UNIVERSIDADE DE LISBOA
FACULDADE DE CIÊNCIAS
DEPARTAMENTO DE BIOLOGIA ANIMAL

Shifting baselines in Mediterranean artisanal fisheries

Pedro Cardoso Leitão

Mestrado em Ecologia Marinha

Dissertação orientada por:
Doutora Rita Pina Vasconcelos
Doutor José António García-Charton

2017

Acknowledgments

To Rita Vasconcelos, Sofia Henriques and José Charton for all the effort, work and friendship in believing in me and helping me during this work.

A special thanks to my mother and my brother for always believing and supporting me in this work and throughout the lifetime and who I thank for shaping the person that I am today.

To Catarina Gil for her love, patience and help in the development of my thesis and for always believing in me although it kept us a part (706.200 km to be precise) for a few months.

To all my dearest friends that I could not spend more time due to the development of this work but are always in my heart.

Research was funded by project BIOCHRONOLOGY (PTDC/AAGGLO/5849/2014). Host institution MARE was funded with project UID/MAR/04292/2013, S. Henriques was funded with a Post-Doc grant (SFRH/BPD/94320/2013) and R.P. Vasconcelos with Investigador FCT Programme (IF/00058/2013) all from Fundação para a Ciência e a Tecnologia, supported by national funds.

Resumo

A sobre-exploração dos recursos marinhos em conjunto com uma insuficiente gestão costeira e pesqueira levou à degradação dos ecossistemas marinhos, à perda de biodiversidade e serviços ecossistémicos a nível global. Especificamente, a intensificação da atividade pesqueira levou ao decréscimo de abundância de espécies ao longo do tempo e com o surgimento de novos pescadores, a perceção da abundância local alterou-se originando uma perceção de quantidade comparativamente a décadas passadas, isto é conhecido com a síndrome de alterações de linhas de base. Este trabalho investiga, através de questionários a pescadores, como a perceção da abundância de pescado se alterou no tempo (1970 até 2016) e espaço (quatro diferentes portos) na pesca artesanal de Múrcia, Espanha. Através dos resultados de 40 questionários, identificou-se um decréscimo de abundância entre 1970-1990 e 2000-2016, e que a maioria das espécies reportadas decresceu (79.7%) tendo algumas como *Octopus vulgaris*, *Merluccius merluccius* e *Polyprion americanus* decrescido de forma mais acentuada o que poderá ser atribuído à sobrepesca e degradação do habitat. Também foi identificado o decréscimo da maioria das características funcionais (92%) durante este período e algumas categorias decresceram de forma mais acentuada como espécies de elevadas profundidades, que se encontram no ambiente bentónico, migradoras de curtas distâncias e que se alimentam de invertebrados. O decréscimo mais acentuado destas características funcionais poderá ser atribuído à falta de plasticidade das espécies a alguns impactos como degradação do habitat e eutrofização ou à pesca de níveis tróficos inferiores. Algumas características funcionais (espécies com comprimento máximo muito elevado, que habitam profundidades muito elevadas, de comportamento solitário, que migram anualmente elevadas distâncias, apresentam elevada mobilidade diária e compreendem uma dieta macrocarnívora), eram mais elevadas nos portos a norte do que a sul. Apesar de algumas categorias funcionais covariarem, este resultado sugere uma influência da reserva marinha de Cabo de Palos – Islas Hormigas (através de transbordamento) nos portos a norte que também têm maior complexidade de habitat. Os resultados do presente estudo, apesar de dependerem da perceção de pescadores e respetivas limitações, demonstram como o conhecimento ecológico local pode ser usado para recolher informação do passado e presente sobre espécies comercialmente exploradas aplicando-a a um nível funcional.

Palavras-chave: Mediterrâneo, alterações de linhas, pesca artesanal, questionários, função

Abstract

The overexploitation of marine resources combined with insufficient coastal and fisheries management have led to the degradation of marine ecosystems throughout the world leading to loss of biodiversity and ecosystem services. Increase in fishing activity led to a decrease in species abundance over time. As new fishers arise, the perception of local abundance changes resulting in a different perception of quantity compared to past decades which is known as "shifting baselines syndrome". This study investigates, through questionnaires, how the perception of fish abundance by fishers changed through time (1970 to 2016) and space (four different ports) in the artisanal fisheries of Murcia, Spain. From the results of the 40 questionnaires made, we identified a decrease between the 1970-1990 and 2000-2016 and that most reported species decreased in abundance (76.7%), more severely the *Octopus vulgaris*, *Merluccius merluccius* and *Polyprion americanus* which may be due to overfishing and habitat degradation. We also identified the decrease of most functional traits (92%) in this period, and especialy trait categories (very deep depths, benthic, yearly migration over small distances and/or invertebrate feeders). These more abrupt decreases may be attributed to lower species plasticity to human impacts such as habitat degradation and eutrophication or to fishing lower trophic levels of the food web. Certain functional traits (very large size, deep maximum depth, solitary behaviour, large distance migratory, very vagile and macrocarnivore diet) were higher in the north ports compared to the southern ports. Although some of this functional trait categories covary, these findings suggest an influence of the Cabo de Palos – Islas Hormigas marine reserve (through spill-over) on the northern ports which also have higher habitat complexity. The results of present study, although dependent on fishers' perceptions and respective limitations, show how local ecology knowledge can be used to collect past and present information on commercial fish species and applied to an abundance and trait-based approach.

Keywords: Mediterranean, shifting baselines, artisanal fisheries, questionnaires, function

Resumo alargado

O ambiente marinho compreende mais de 70% da superfície terrestre. Este ambiente possui uma vasta diversidade de ecossistemas marinhos que desempenham funções importantes quer a nível ecológico (sequestro de dióxido de carbono atmosférico, reciclagem de nutrientes, regulação da qualidade da água), quer a nível social (transporte, turismo). Apesar de dependermos fortemente destas funções, elas não têm sido devidamente acauteladas na gestão ambiental. As múltiplas pressões a que o ambiente está exposto, e designadamente a biodiversidade do meio marinho (sobrepesca, destruição do habitat, poluição, alterações climáticas), condicionavam a elaboração de um tratado internacional, a Convenção sobre a Diversidade Biológica, que entrou em vigor em 1993. A nível do ambiente marinho, tem como objetivo contribuir para a sua proteção, de maneira a gerir de forma sustentável a exploração dos seus recursos vivos, incluindo a redução do decréscimo de espécies ameaçadas, e também para a salvaguarda dos ecossistemas que prestam serviços e as comunidades humanas que deles dependem. Na sequência deste tratado, e para preservar os mananciais de peixes e exploração de recursos vivos, a União Europeia, desenvolveu legislação (como a Diretiva Quadro Estratégia Marinha) e adotou políticas comunitárias (como a Política Comum das Pescas). No contexto destes instrumentos a União Europeia avalia os níveis de exploração do pescado e atribui cotas de captura aos diferentes estados membros. O Mar Mediterrâneo, partilhado por 22 países, constitui um dos ecossistemas marinhos mundiais mais ameaçados. Para tal contribuem a sobrepesca, a degradação do habitat e a poluição de origem terrestre tais como a eutrofização (agricultura e descargas poluentes), e as modificações da costa e a urbanização. As alterações climáticas e a introdução de espécies não indígenas também têm contribuído para o problema. A sobrepesca foi identificada como uma ameaça importante. A maioria dos recursos vivos do Mar Mediterrâneo são sobre-explorados (96%), existindo um elevado número de capturas ilegais. Apesar de 9.5% da área marinha do Mar Mediterrâneo ser protegida, são necessários mais esforços para implementar medidas que regulamentem no sentido da sua conservação, para o que contribuirá o conhecimento da evolução das pescas ao longo do tempo. Conhecer a evolução da abundância de captura de pescado ao longo do tempo não é fácil, dada a dificuldade em obter dados passados, com frequência escassos ou inexistentes, especialmente em países em vias de desenvolvimento. Nestas circunstâncias, pode-se em parte reconstruir capturas e abundâncias de décadas passadas pela perceção intrínseca das pessoas que dependem da pesca, permitindo uma abordagem através do conhecimento ecológico tradicional e local.

O estudo aqui apresentado teve como objetivo avaliar alterações de linhas de base na pesca artesanal no Mar Mediterrâneo, através da perceção que os pescadores têm da abundância local e das suas modificações comparativamente a décadas passadas, de forma a contribuir para uma melhor gestão das pescas e da costa. O estudo foi realizado na região de Múrcia, Espanha (Mediterrâneo Oeste), pertencente à região marinha das Baleares (como definida pela Organização para a Alimentação e Agricultura em 2004). Foi considerada a variação da pesca comercial artesanal de pequena escala no tempo (entre 1970 e 2016) e no espaço (quatro portos). Foram realizados inquéritos a 40 pescadores artesanais, sendo a seleção dos inquiridos feita através do método de amostragem "bola de neve". Os questionários eram constituídos por seis capítulos, referentes a: informação pessoal, informação sobre o barco, perceção das linhas de base, alterações climáticas, esforço de pesca e captura acidental de aves marinhas. Para a classificação das características funcionais de cada táxon identificado pelos pescadores (n=31) foram utilizadas características funcionais. Foram identificados o comprimento máximo, a profundidade máxima, o habitat, a dieta, o comportamento de agrupamento, a territorialidade, e ainda o movimento das espécies, quer anual, quer diário. Foi também avaliado o valor económico das espécies. Os dados recolhidos foram analisados estatisticamente.

No que se refere ao período de tempo avaliado, os pescadores entrevistados descreveram um decréscimo da abundância de pescado ao longo das décadas (entre as décadas de 1970-1990 e 2000-

2016). Estes dados confirmam os descritos por outros autores, que sugerem que o aumento do esforço de pesca e a insustentabilidade na exploração de pescado originaram a sobre-exploração dos mananciais do Mediterrâneo Oeste. A nível das espécies verificou-se que 76.7% das espécies reportadas decresceram entre as décadas de 1970-1990 e 2000-2016. Destas espécies, algumas decresceram mais abruptamente (*Octopus vulgaris*, *Merlucius merlucius* e *Polyprion americanus*), sendo que as razões para o decréscimo estão provavelmente relacionadas com a sobre-exploração dos mananciais (nomeadamente a pescada, *Merlucius merlucius*) e com a importância relativa destas espécies para a economia nacional do pescado. Apesar de alguns autores sugerirem a possibilidade de o grupo dos cefalópodes tender para um aumento global, a escassez de dados no que respeita ao estado das populações de polvos (*Octopus vulgaris*) sugere que se tenha uma gestão de precaução. Relativamente ao cherne (*Polyprion americanus*), o estado dos mananciais e impactos da pesca continuam por investigar uma vez que existe escassez de dados relativos ao estado das populações no Mar Mediterrâneo. Recorrendo a análises baseadas nas características funcionais verificou-se uma diminuição significativa ao longo do tempo na maioria das características (92%). A perda mais severa nas categorias funcionais foi verificada nas espécies de elevadas profundidades, nas que se encontram no ambiente bentónico, nas migradoras de curtas distâncias e nas que se alimentam de invertebrados. O decréscimo poderá estar associado à maior (ou menor) plasticidade das espécies para se adaptarem a novas condições do meio face aos impactos antropogénicos. Estes impactos incluem a sobrepesca, a degradação do habitat através da poluição, como a eutrofização, e a modificação costeira devido ao aumento da população e do turismo. Através da análise das características funcionais das espécies entre os diferentes portos verificou-se que os dois portos a norte apresentaram valores mais elevados para as espécies com categorias de comprimento máximo muito elevado, que habitam profundidades muito elevadas, de comportamento solitário, que migram anualmente elevadas distâncias, que apresentam elevada mobilidade diária e que têm uma dieta macrocarnívora. As diferenças geográficas obtidas (maior abundância a nível geral e algumas características funcionais nos portos a norte) poderão dever-se à existência de uma área marinha protegida (Cabo de Palos – Islas Hormigas) estabelecida há mais de 20 anos, que se encontra entre os dois portos a norte, admitindo-se transbordo de biomassa para as áreas adjacentes, como verificado por outros autores. Para as diferenças geográficas admite-se ainda ter contribuído a complexidade do habitat do tipo de recife rochoso na região a norte, que amplia a área de superfície e favorece ecossistemas mais ricos e abundantes em espécies. O presente estudo possibilitou observar as alterações do decréscimo generalizado e a nível das espécies de pescado ao longo dos últimos 50 anos e quais as espécies mais afetadas. A nível das funcionalidades desta fração da comunidade de peixes, foi possível verificar a diminuição de capturas de várias características funcionais a nível temporal e diferenças a nível espacial. Apesar dos resultados terem sido obtidos de acordo com as boas práticas recomendadas, devem ser interpretados cautelosamente, atendendo a que os dados foram obtidos através de questionários e focalizaram-se apenas numa parte da comunidade de peixes. No entanto, devido à escassez de informação nesta área, e para estabelecimento de linhas de base para a conservação de ecossistemas marinhos, devem ser consideradas a importância deste tipo de recolha e a sua interpretação.

As comunidades de peixes e invertebrados são fundamentais para o ecossistema marinho (controlo populacional, reciclagem de alimento) sugerindo-se estudos no sentido de avaliar qual o impacto da sua exploração sobre os ecossistemas, de forma a melhor adequar as artes e técnicas de pesca. As áreas marinhas protegidas estabelecem importantes abrigos para várias espécies, sugerindo-se estudos no sentido de compreender o efeito do transbordo de biomassa e a sua importância ecossistémica. Devido ao aumento de novas ameaças no Mar Mediterrâneo, designadamente alterações climáticas e introdução de espécies não indígenas, mais estudos devem ser realizados de forma a avaliar se os outros impactos interferem com a abundância de espécies pescadas, no sentido de melhorar a gestão das pescas.

Através da investigação dos impactos crescentes sobre o Mar Mediterrâneo e das suas relações, poder-se-ão desenvolver medidas mais consistentes para a proteção da sua biodiversidade, e dos serviços de ecossistema que este Mar providencia.

Palavras-chave: Mediterrâneo, alterações de linhas, pesca artesanal, questionários, função

Conferences

Leitão P, Henriques S, García-Charton JA, Lorenzi M, Vasconcelos RP (2017) Shifting baselines of artisanal fisheries in the west Mediterranean (Murcia, Spain). In: Oceans Past VI international conference. Sesimbra, (oral presentation)

INDEX

List of figures

List of tables

General Introduction

Marine ecosystems comprehend approximately 71% of the surface of the planet and contain about 97% of water on Earth. Marine ecosystems support 25% of all known species, but it is estimated that another 91% still remain undiscovered (Mora et al. 2011), and play crucial ecological functions, such as sequestration of CO_2 in larger amounts than the terrestrial biosphere (Sabine 2004), nutrients cycling and the regulation of their availability for marine species (Attiwill 1983), as well as providing crucial services such as maintaining water quality (Worm et al. 2006) and food supply for a world human demand of 20 kg per capita (FAO 2016a). Socially, marine ecosystems provide the means of maritime transportation and ensure recreational use of certain areas for leisure (e.g. coastal tourism; Worm et al. 2006). Although some of these ecological functions are well studied, many of the processes that influence the provision of ecosystem services to Humankind are not accounted for when managing the marine environment (Costanza 1999, Liquete et al. 2016).

Marine ecosystems are currently at risk worldwide (Worm et al. 2006, Selig et al. 2013). Multiple impacts such as overfishing, habitat degradation, pollution and climate change (Jackson et al. 2001, Halpern et al. 2008) are influencing marine biodiversity and the ecosystems capacity to perform the important, above mentioned, ecological processes (Hawkins et al. 2003, Worm et al. 2006). In the effort to limit biodiversity loss, in 1993 the Convention for Conservation of Biodiversity came into force, and later the Aichi Biodiversity targets were proposed to be achieved by 2015 and 2020. Among other targets, they include to (i) sustainably manage and harvest fish and invertebrates, and (ii) identify and reduce the observed decline of threatened species and safeguard ecosystems that provide essential services and their local communities (CBD 2013).

The Mediterranean Sea is one of the most threatened marine ecosystems worldwide (Coll et al. 2010). Overfishing of fish stocks like hake, red mullet and sardine (Fernandes et al. 2017), habitat degradation and land-based pollution have been the major impacts in Mediterranean Sea (Coll et al. 2010). While eutrophication due to agriculture and sewage discharges may cause episodes of harmful algal blooms that disrupt food webs (Heisler et al. 2008), coastal modification and urbanization degrade productive near-shore ecosystems (e.g. wetlands, seagrass meadows, coastal lagoons; Beck & Airoldi, 2007). In addition, climate change (Coll et al. 2010) and the invasion of alien species throughout the Suez Canal (Galil et al. 2014) are emerging and urgent issues that could modify marine ecosystems (Cheung et al. 2009). In the Mediterranean Sea, the dependency for food is evident since 22 countries in three different continents share this sea. Because of this, overfishing is a major issue in local ecosystems and fish stocks of the Mediterranean, where increasing landings of commercially exploited species, since the 1990, have been reported (Vasilakopoulos et al. 2014) and all assessed stocks are being unsustainably exploited (Fernandes et al. 2017). Overfishing is a major threat in marine ecosystems and arises when the exploration of fish stocks is faster than their ability to replenish (Jackson et al. 2001). The world population has been growing exponentially since the industrial era and with it food demand grows, with fish products being one of the main protein sources (FAO 2016a). From a simple, artisanal, subsistence and near shore activity, fisheries evolved to a commercial, complex and more profitable activity with larger catches and new, deeper, fishing grounds being exploited due to technological and preservation storage innovations (Sahrhage & Lundbeck 1992). Commercial fisheries worldwide can be divided into two major categories: small-scale and commercial fisheries. While small-scale artisanal fisheries consist of small capital investments, technologically simple gear and vessels with small catches for subsistence or local markets (Kurien & Willmann 2009), large-scale commercial fisheries focus on profiting from fisheries with more complex and specialized gear, larger autonomy and coastal distance and higher catches when compared to small-scale (Carvalho et al. 2011). In the Mediterranean, small-scale fisheries represent 80% of total fisheries, employ 55% of fishers but only accounts for 12% of all landings (FAO 2016b). While strict regulations for pollution, coastal management and fishing exists (Cacaud 2005), it is necessary to minimize these impacts on ecosystems, for example through the implementation of marine protected areas (Gabrié et al. 2012, Bastari et al. 2016) and the identification of eutrophic areas as well as their respective trends (Karydis & Kitsiou 2012).

In order to protect the marine environment across Europe, the European Union set a series of steps by implementing the Marine Strategy Framework Directive (The European Parliament and the Council of the European Union 2008) in order to achieve a good environmental status of marine waters by 2020. Its objective is to maintain ecosystems function and resilience (capacity to absorb human impacts), to prevent the decline of biodiversity, and to control substance, energy and noise pollution (The European Parliament and the Council of the European Union 2008). This is achieved through a series of procedures that start by the assessment of the marine environmental status, followed by setting up proper monitoring protocols, and establishing and implementing adequate management measures. Related to the fisheries descriptor, EU member states should assess mortality rates, biomass of spawning stock and the age and size structure of fish populations of commercially exploited fish and shellfish stocks (European Commission 2017a). In the fisheries sector, the Common Fisheries Policy was firstly established in 1970 although designed primarily to give equal access to European waters and fishing grounds, its aims is also to seek for an environmentally, economically and socially sustainable fisheries (European Commission 2017b). Since fisheries need to be sustainable and ensure their availability for future generations, fisheries management regulates both the input (access to waters, fishing effort and technical measures) and the output (total allowable catches and quotas) of fishing fleets (European Commission 2017b).

To evolve towards sustainable fisheries, management actions need to decrease fisheries impacts on species and habitats. Ideally, fisheries should be highly selective for the targeted species to reduce bycatch, unaccounted mortality or ghost fishing (FAO 1995). Management tools for fisheries sustainability include reducing catches of non-targeted species (through for examples sorting nets in trawlers), area restrictions (protected areas, including no-take zones) or time restrictions (closed seasons) to ensure productive capacity of stocks, minimal landing sizes to protect certain life stages and fishing quotas controlling landings (Kurien & Willmann 2009).

Fisheries management relies on key information including species official catches (i.e. landings) and stock assessment data (i.e. spawning stock biomass). In the European context, the assessment of fish stocks is transmitted from the Scientific, Technical and Economic Committee for Fisheries (STECF), International Council for the Exploration of the Seas (Atlantic Ocean and Baltic Sea) and General Fisheries Commission for the Mediterranean (Mediterranean and Black Seas) to the European Commission (European Commission 2017c). While the STECF is the only advisory body that reports directly to the European Commission, the ICES and GFCM are secondary sources that the EU might reach to complement their fisheries management advice in implementing the Common Fisheries Policy (European Commission 2017c). While stock assessment can be complicated by insufficient or inexistent biological data (Oliver 2002), official landings reported by each member state sometimes lack significant catches that are not accounted for (illegal unreported and unregulated; IUU; Agnew et al. 2009, Coll et al. 2015) which may lead to underestimation of stocks exploitation rates and could result in overfishing. This is of particular concern in the Mediterranean Seas, as overexploitation of assessed fish stocks is concerning (93%; WWF 2016) and IUU comprehend significant catches, especially in the western Mediterranean area like Spain (Pauly et al. 2014).

The objective of this study is to identify changes in fishers' perception in artisanal fisheries at a local scale (Region of Murcia, Spain, SW Mediterranean), and to investigate if fisher’s questionaries’ can be used as a tool for fisheries and coastal management.

Shifting baselines in artisanal fisheries

Leitão P[1], García-Charton JA[2], Henriques S[1], Vasconcelos RP[1]

[1] MARE - Marine and Environmental Sciences Centre & FCUL - Faculdade de Ciências da Universidade de Lisboa, Campo Grande, 1749-016 Lisboa, Portugal;
[2] Departamento de Ecología e Hidrología, Universidad de Murcia, Campus de Espinardo, 30100 Murcia, Spain;

Introduction

The overexploitation of marine fisheries resources together with an unsustainable use of coastal areas have led to the degradation of marine ecosystems worldwide leading to loss of biodiversity and ecosystem functioning and services (Worm et al. 2006, Halpern et al. 2008). The Mediterranean sea is no exception, with a coastal population of 250 million people, over 96% of assessed fish stocks over-exploited (European Comission 2015) and intense human activities and impacts on marine biodiversity and habitats (Coll et al. 2012). Currently, the major pressures on marine ecosystems of the Mediterranean are habitat loss and degradation, overexploitation of fish stocks, pollution and more recently introduction of non-indigenous species mainly through the Suez Canal (Coll et al. 2010, Galil et al. 2014). Today, the Mediterranean Sea is one of the most human impacted marine ecosystems in the world (high to very high levels; Halpern et al. 2008).

Assessing the status of marine ecosystems and implementing effective management and conservation strategies (e.g. marine protected areas - MPAs) is essential for protecting biodiversity (García-Charton & Pérez-Ruzafa 1999). Finding the balance between a sufficient exploitation of natural resources to meet demands and a sustainable use of marine ecosystems is an immense challenge (FAO 2016a). It is increasingly accepted that to accurately assess this relationship an ecosystem-based management (EBM) should be taken into account (Christensen et al. 1996), but EBM is in an early stage due to its complexity. For many decades management was made on a species- or sector-level (e.g. fisheries) without relating to other ecosystems processes or services (Zerhouni 2004). In contrast, ecosystem-based management can consider species according to their functions in the ecosystem and their relationships with other organisms and physical processes, whilst also taking into account human interactions (Long et al. 2015).

Meaningful assessments of marine ecosystems (including EBM) require identifying baselines (i.e. pristine/undisturbed state of marine ecosystems without or with minimal anthropic impacts) to establish reference conditions. These baseline/reference conditions guide management and conservation actions aiming at reducing anthropogenic impacts, while protecting, preserving and restoring marine ecosystems (The European Parliament and the Council of the European Union 2008). In the case of fisheries, these baselines are used to meet the EU objectives of ensuring the availability for present and future generations of fish stocks and fisheries sector (Council of the European Union 2002, European Union 2014). The assessment of stock changes is done by comparing observed values with these baseline/reference points (Markham & Browne 2007, Knowles et al. 2015), to understand how the environment evolved through time and which human activities influenced them (Edgar et al. 2004).

In addition, recent European directives call for the integrated assessment of marine ecosystems, such the Marine Strategy Framework Directive which aims to achieve "good environmental status" (GES) in marine ecosystems by 2020 (The European Parliament and the Council of the European Union 2008). However, defining how ecosystems were in a previous pristine/undisturbed state (i.e. in good environmental status) is difficult in many countries/regions due to low data availability (Honey et al. 2010). Without knowledge on previous conditions, our understanding of current conditions is compromised, especially through a "shifting baselines syndrome": as each generation of scientists/managers/users tends to accept as a baseline the ecosystem state at the beginning of their careers and use it to evaluate changes, through generations there is a gradual shift of the baseline leading to use of inappropriate reference points (Pauly 1995). This phenomenon leads to false perceptions about fish communities' status (e.g. composition, assemblage structure) namely underestimated or unrecorded changes (Lozano-Montes et al. 2008), leading to insufficient and/or inadequate management targets (Pauly 1995). Countries from the European Union (EU) have been assessing Mediterranean fish stocks in the last 40 years (Colloca et al. 2013), and a more continuous and improved fisheries management started in the 1990s through the General Fisheries Commission for the Mediterranean (GFCM; Oliver, 2002). However, reference points in the Mediterranean countries are almost inexistent and non-consensual (Cardinale et al. 2013, Boyes et al. 2015), due to short time data series (20 years), to the establishment of references after overfishing of stocks, and to inconsistent techniques (Fromentin & Powers 2005).

Assessment of fish populations can use fisheries-dependent data (such as landings and logbooks information) or fisheries-independent data (like research surveys) on species catch per unit effort (CPUE), size, age distribution (Cooper 2006). With this information, stock assessment models can be used to estimate for instance catch, size and age composition, and other techniques can be used to estimate changes in populations and ecosystems (Abaunza et al. 2003, Sondre 2003, Cadrin & Dickey-Collas 2015). But in many countries, especially developing ones, there are important data deficiencies (Hoggarth et al. 2006). In these cases, local ecology knowledge (LEK) or traditional ecology knowledge (TEL) especially from fishers (Rasalato et al. 2010) can be useful for assessments (Bunce et al. 2008, Bender et al. 2013). Fishers' empirical knowledge of the environment and fish ecology can provide crucial information about the status of fishing stocks and ecosystems conditions in past decades (Ferguson et al. 1998, Huntington 2000, Moller & Berkes 2004, Johannes et al. 2008). Additionally, historical ecology uses past records such as fishers logbooks, catches or exportations to estimate previous distribution or abundance of fish stocks, although these data can be sporadic and not representative of the ocean in the past (Lotze & Worm 2009).

In this study, fishers' interviews were done in an artisanal fishing community in the region of Murcia to explore shifting baselines phenomenon and understand how fishers perceive the changes of fish since 1970 on the south-western Mediterranean Sea where long-time series are scarce. This work aims to assess the trends of fish populations and fishing effort in a long data series period (1970 to 2016), by reconstructing past decades based on fishers' perception, while identifying if a shifting baseline phenomenon is occurring in the coast of Murcia. This approach will improve the understanding and establishment of baselines for fish populations, especially in data-poor contexts.

Material and Methods

Study area

The present study was conducted in South-eastern Spain in the Murcia region (Fig. 1), i.e. Balearic marine region of the Food and Agriculture Organisation (FAO 2004) and south-western Mediterranean and Alboran Sea of the marine ecoregions of the world (Spalding et al. 2007). This area is characterized by a short continental shelf except for the Cabo de Palos – San Pedro del Pinatar coast that comprehends 10 km of shelf. This coast line is influenced by the large scale deep water current, parallel to the coastline from North towards South and intense mesoscale phenomenon’s like gyres and mid-sea eddies (Robinson et al. 2001). As a Mediterranean temperate realm, this habitat is characterized by rocky or detritus bottoms and *Posidonia oceanica* beds, harbouring a high biodiversity and habitat variety (García-Charton et al. 2015).

In 1995, Cabo de Palos – Islas Hormigas marine reserve was established with the goal of protecting the marine communities and human populations that depend on local fisheries (Consejero de Agricultura Ganadería y Pesca 1995). In this area, shallower bottoms harbour rocky boulders of various sizes interspersed with *Posidonia oceanica* meadows forming a narrow belt following the coast, while at deepest portions (>20 m), detritic formations predominate, after which a series of steep rocky shoals and small islands are aligned seawards from the cape to the north-east, where photophilous, pre-coralligenous and coralligenous (mainly gorgonians) present a very good development (García-Charton et al. 2010). The area (1831 ha) is established between San Pedro del Pinatar and Cartagena and has a no-take zone (where all activities are forbidden except scientific research and monitoring) and a buffer area, where some artisanal fisheries and commercial SCUBA diving are regulated (García-Charton et al. 2010).

The fishing activity in the Murcia region is mainly composed of artisanal fisheries, bottom trawlers and purse seine that predominantly target large pelagic species (Coll et al. 2015). In 2015, the number of fishing vessels in Murcia was 188 with an average power of 109 kW and 70% of the boats have less then 10 meters length (Ministerio de agricultura y pesca 2016). The local fishing activity has been decreasing through the last decades and fish landings have reduced from 2.000.000 tons in 1985 to below 1.500.000 tons in 2010 (Coll et al. 2015).

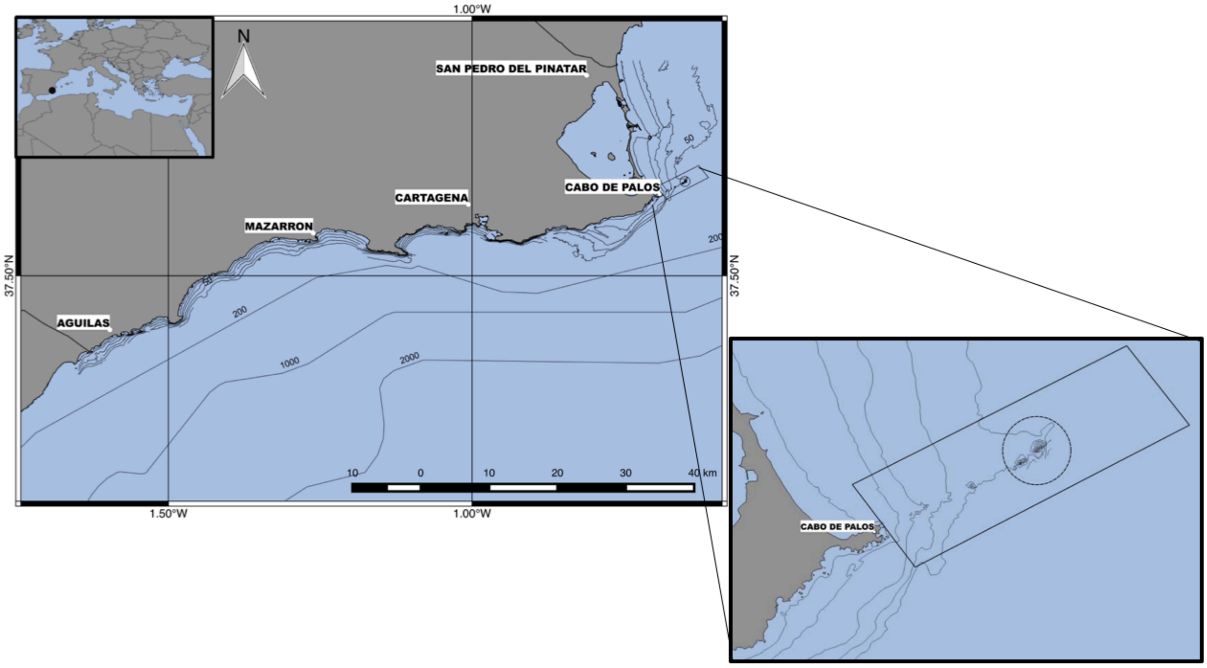


Figure 1. Map of the coast of the Murcia region with sampling ports (North to South: San Pedro del Pinatar, Cartagena, Mazarron, Águilas) in the context of the Mediterranean Sea (upper left corner) and the zoom section of the Cabo de Palos – Islas Hormigas marine reserve (lower right corner).

Sampling method

Sampling was made in the main fishing ports in the region: San Pedro del Pinatar, Cartagena, Mazarrón and Águilas. We interviewed artisanal fishers with no regard to their age through a snowball sampling procedure which consists of asking the last interviewed person where to find the next person to survey (Goodman 1961). The questionnaire was subdivided into six chapters, namely on: personal information, boat information, perception of baselines, climate change, fishing effort and by-catch of seabirds (Appendix I).

Regarding the perception of baselines, we asked fishers: to rate how did fish abundance change from the 1970s to present (2016) throughout decades (with abundance of each taxon from 5 – always caught in large amounts to 0 – never caught). We also asked what was the main fishing gear used, the largest total catch (in kg) in a fishing day, and the largest single specimen caught for each taxon (in m). We also asked where are their main fishing grounds and if they changed through time (Appendix I).

All information given by the fishers was treated anonymously and is protected under the organic law 15/1999 from 13 December about Personal Data Protection in Spain. No question in the questionnaire was mandatory and all the participants had to sign a form to validate the data.

Functional trait classification

For each taxon (n=31) reported by the fishers in the interviews, we characterized a set of nine traits, to describe their features that determine the way they use the habitats aiming at identifying relations to local fisheries practices (Table 1; Appendix II). We retrieved traits from online databases (e.g. Fishbase, Food and Agriculture Organization - FAO - worksheets) complemented with published scientific literature.

We characterized the maximum reported length (i.e. small, medium, large and very large), the depth range occupied (i.e. shallow, medium, deep, broad), habitat (i.e. pelagic, demersal, benthic) and diet (i.e. omnivore, planktonivore, invertebrate feeder, macrocarnivore; Table 1). We also characterized traits describing behaviour, namely schooling behaviour (i.e. solitary, facultative schooler, schooler; where mating pairs were considered solitary) and territoriality (i.e. territorial and non-territorial). In addition, we characterized traits related to species movement, namely their yearly displacement (i.e. small, medium, large) and daily mobility (i.e. sedentary, vagile and very vagile). All species traits were characterized in an adult stage (Table 1).

Finally, we described whether the species had direct economic value in fisheries in that region (i.e. commercial and non-commercial). Although this is not a functional trait, targeted species are more subjected to fishing activity and thus to being reported by fishers.

Table 1. Functional traits and respective categories, description and specific relevance.

Trait	**Category**	**Description**	**Relevance**
Maximum body size	Small	< 20 cm	Reflects the position of the species in the food web, species abundance and metabolic rates. Trait categories adapted from Claudet et al. 2010, Henriques et al. 2017.
	Medium	20 - 60 cm	
	Large	60 - 100 cm	
	Very large	> 100 cm	
Maximum depth	Shallow	< 50 m	Indicator of the physical pressure and temperature of the different depths. Used to describe habitat. Trait categories adapted from Henriques et al. 2017.
	Medium	50 - 200 m	
	Deep	200 - 500 m	
	Very deep	> 500 m	
Habitat	Pelagic	Depends on the upper layers of the water column	Indicates the main habitat of which the species uses and depends on (Claudet et al. 2010).
	Demersal	Strongly depends on the ocean bottom (to feed or protection) but swims freely in the water column	
	Benthic	Lives and depends on the ocean bottom (exclusive benthic)	
Diet	Omnivore	Feeds on detritus (≥25%), macroalgae (≥25%) and epi and infauna	Reflects the position of the species in the food web, the influence on other species and their habitat. Trait categories adapted from Henriques et al. 2017.
	Planktonivore	Feeds on planktonic invertebrates	
	Invertebrate feeder	Feeds predominantly on non-planktonic invertebrates (≥ 50 % weight)	
	Macrocarnivore	Feeds on both fish and medium-large invertebrates (≥ 50% weight)	

Table. 1 (continued)

Trait	Category	Description	Relevance
Schooling behaviour (> 2 individuals)	Solitary Facultative schooler Obligate schoolers	Fish that are nearly always solitary Fish that can be seen in school aggregations Fish that are always in schools	Reflects the species density per area in response to protection, food search efficiency (Pitcher 1986) and likelihood for fishing in large quantities. Trait categories adapted from Claudet et al. 2010.
Territoriality	Territorial Non-territorial	Territorial species Non-territorial species	Indicates the protection range of the species, aggressiveness and small scale mobility. Trait categories adapted from Claudet et al. 2010.
Yearly displacement	Small Medium Large	< 100 m 100 - 10000 m > 10000 m	Relates to the mesoscale distribution of the species and their large-scale mobility capacity. Trait categories adapted from Claudet et al. 2010.
Mobility	Sedentary Vagile Very vagile	Swims <50% of the time Swims ≥50% of the time Almost always swimming	Reflects the behaviour and agility of the species in the water column. Trait categories adapted from Claudet et al. 2010.
Commercial or bycatch value	Commercial Non-commercial	Commercial species Non-commercial species	Reflects the commercial value of the species and evaluates the importance of each species to fisheries. Trait categories adapted from Claudet et al. 2010.

Fishers reported mostly fish, but also identified other species/groups of species of crustaceans and molluscs (*Sepia officinalis*, *Octopus vulgaris*, *Palinurus* sp., *Hommarus gammarus*, Teuthida and *Palaemon* sp.) which were treated in the same manner in our study. Some of the taxa could not be resolved at species-level (Scorpaenidae, Teuthida, Epinephilinae, *Palinurus* sp., *Thunnus* sp. and *Palaemon* sp.).

The further identification of some groups (Scorpaenidae, Teuthida, *Epinephelus* sp., *Palinurus* sp., *Thunnus* sp. and *Palaemon* sp.) was not possible. Missing information for the diet of Scorpaenidae family was complemented with information of *Scorpaena porcus* and *Scorpaena notata* since they are a common species of this family in the Mediterranean (Morte et al. 2001). The same procedure was done for the Teuthida order which was complemented with information of *Loligo vulgaris*, the genus *Epinephelus* sp. with the *Epinephelus marginatus*, *Palinurus* sp. with *Palinurus elephas*, *Thunnus* sp. with *Thunnus thynnus* and *Palaemon* sp. with *Palaemon serratus*. The species used to complete the traits were chosen because of their abundant in the Mediterranean and/or commercial value for fisheries.

Data analysis

We ran one-way and two-way PERMANOVA tests, using raw data of abundance scores (with all specimens together), testing the null hypothesis of no difference between groups (Anderson 2001). We considered the factors: decades, class decades (1970-1990 and 2000-2016; since these two periods were significantly different according to the PERMANOVA test), port, age [through raw age, 2 level (23-55; 56-82) and 3 level (23-44; 45-57; 58-82) class age]. In the two-way PERMANOVA, the factors used were: ports; age, 2 level class age, 3 level class age; decades, class decades; and all interactions between them. We used confidence interval of 95% ($P < 0.05$), Euclidean distances and 9999 permutations. Subsequently we used pairwise tests ($P < 0.05$) with no P-value adjustment to explore the identified differences. As PERMANOVA is sensitive to differences in multivariate dispersion, we first test the homogeneity of multivariate dispersion of the data using a PERMDISP routine (Anderson et al. 2008). The PERMANOVA procedure between class decades was repeated to analyze differences of individual species and functional traits between class decades and ports.

To evaluate the taxa which contributed most to differentiate class decades we implemented a similarity percentage procedure (SIMPER) in a presence/absence matrix - since the raw data had high number of missing values and this procedure was not possible.

For all data analysis, we used R software (R Core Team 2015) version 3.2.3 for restructuring and arrange data (packages tidyr and reshape2; Wickham 2007, 2017) and PERMANOVA analysis (package vegan; Oksanen et al. 2016).

Results

Concerning the catch reported by decades, or dividing the time between two class decades (before 90's and after 2000's), according to most fishers, the abundance of fish declined in time with the most evident change before 1990's and after 2000's (Fig. 2 and 3). PERMANOVA and pair-wise tests showed that decades before 2000 are significantly different from those including and after 2000 (Tables 2 and 3). In addition, the 2000 decade was also significantly different from the subsequent decades. In all, this identifies a breakpoint in abundance between years 1990 and 2000.

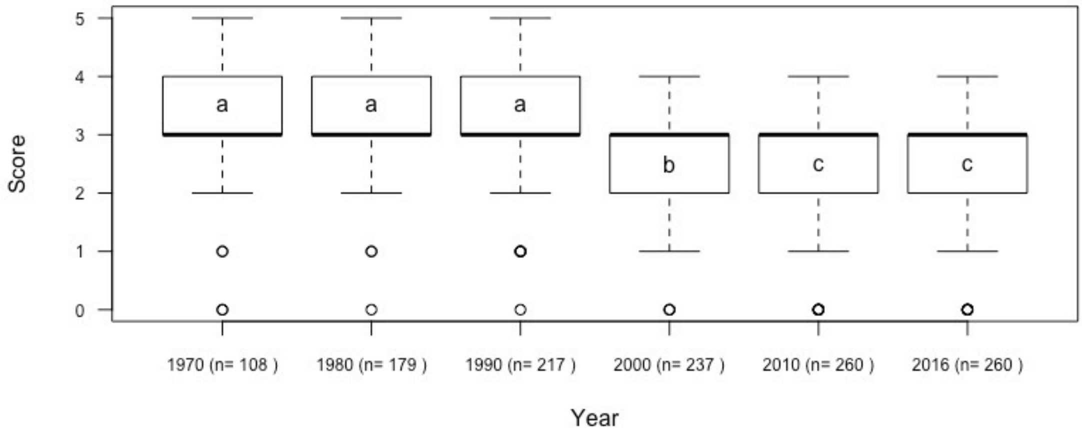


Figure 2. Boxplot of fishers scores to taxa catches in the Mediterranean throughout the last decades (1970 to 2016) and the respective sample size (n is the number of times a species is referred by a fisher in a total of 40 interviews) of each year. Different letters represent significantly different decades (for P < 0.05).

Figure 3. Boxplot of fishers scores to taxa catches in the Mediterranean between the two class decades (1970 to 1990 and 2000 to 2016) and the respective sample size (n is the number of times a species is referred by a fisher in a total of 40 interviews) of each class. Different letters represent significantly different decades (for P < 0.05).

Table 2. Results of PERMANOVA analysis of the Euclidean dissimilarities of the fisher's abundance score in decade capture (1970 to 2016) and class decade (1970 to 1990 and 2000 to 2016); Df = degrees of freedom; Pseudo-F = F value by permutation. Bold indicates statistical significance (P < 0.05); P-values are based on 9999 permutations.

	Df	Pseudo-F	P-value
Decade capture	5	26.271	**0.001**
Class decade	1	124.560	**0.001**

Table 3. Results of pairwise tests of the fisher's abundance score between year captures from 1970 to 2016 of the Mediterranean. Table shows P-values for the different tests; *ns* = non-significant P-values at P < 0.05.

	1970	1980	1990	2000	2010
1980	ns	-	-	-	-
1990	ns	ns	-	-	-
2000	<0.001	<0.001	<0.001	-	-
2010	<0.001	<0.001	<0.001	0.028	-
2016	<0.001	<0.001	<0.001	0.036	ns

Concerning ports, San Pedro del Pinatar has higher scores compared to the rest of the ports (Fig. 4). PERMANOVA analysis shows that fishing ports are statistically different (P-value = 0.0001) and pairwise tests showed that San Pedro is significantly different from Águilas and Mazarrón but not Cartagena (Table 4).

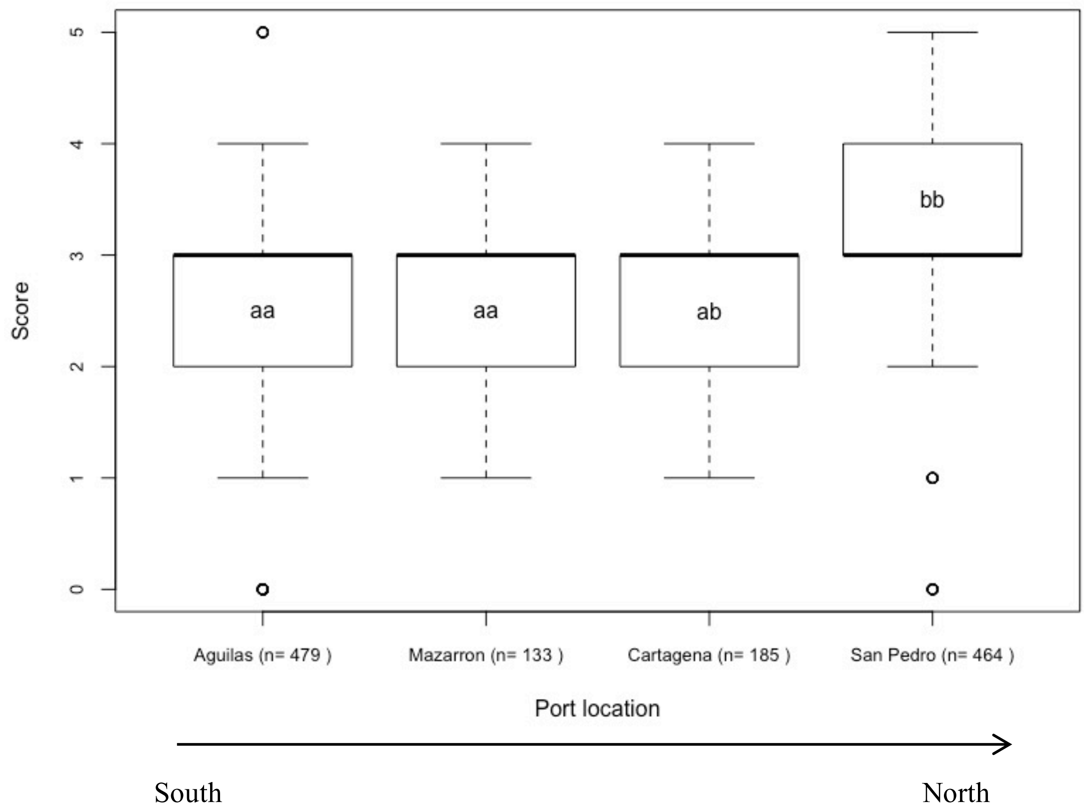


Figure 4. Boxplot of fishers' abundance scores for abundance according to each port (Águilas, Mazarrón, Cartagena and San Pedro del Pinatar) of the Mediterranean region and the respective sample size (n is the number of times a species is referred by a fisher in a total of 40 interviews). The locations are ordered geographically (from South to North). Different letters represent the groups formed by the post-hoc pairwise comparison (for P < 0.05).

Table 4. Results of pairwise tests of fisher's abundance scores between the Mediterranean ports of Águilas, Mazarrón, Cartagena and San Pedro del Pinatar. Table shows P-values for the different tests; *ns* = non-significant P-values at P < 0.05.

	Águilas	Cartagena	Mazarrón
Cartagena	ns	-	-
Mazarrón	ns	ns	-
San Pedro	<0.0001	ns	0.0210

The age of fishers had a significant effect on scores of abundances, with no effect of 2 level class age and a marginal effect of 3 level age class (Table 5) observed between classes "young" and "adult" (Pairwise: $p = 0.028$; $p < 0.05$).

Table 5. Results of PERMANOVA analysis of dissimilarities (Euclidean) of fisher's abundance score for age, and 2 (young and old) and 3 level (young, adult and old) class age; Df = degrees of freedom; Pseudo-F = F value by permutation. Bold indicates statistical significance (P < 0.05); P-values are based on 9999 permutations.

	Df	Pseudo-F	P-value
Age	26	2.9542	**0.001**
2 level class age	1	0.5910	0.461
3 level class age	2	2.4617	0.085

Among the two-way PERMANOVA tests performed (Table 6), only three interactions were significant: Class decade x Port, Decade x Port, and Class Decade X Age.

Table. 6 Results of two-way PERMANOVA analysis of the Euclidean dissimilarities for the fishers' abundance scores between each variable (decade, class decade, age, 2 and 3 level class age, and port). Df = degrees of freedom; Pseudo-F = F value by permutation; *ns* = non-significant. Statistical significance (P < 0.05); P-values are based on 9999 permutations.

	Df	Pseudo-F	P-value
Decade X age	93	0.6967	0.986
Decade X 2 class age	5	0.1815	0.968
Decade X 3 class age	9	0.5667	0.829
Decade X port	15	2.2393	**0.005**
Class decade X age	20	2.2841	**0.001**
Class decade X 2 class age	1	0.9503	0.333
Class decade X 3 class age	2	1.7325	0.175
Class decade X port	3	10.033	**0.001**
Age X port	6	0.9617	0.447
2 lvl class age X port	3	1.4939	0.213
3 lvl class age X port	5	1.1428	0.339

Although scores decreased significantly through time in each of the four ports, the significant interactions of Class Decade X Port (Fig. 5; Table 7) and Decade X Port (results not shown) indicate that this decrease was more pronounced in Águilas (since abundance scores in Águilas in 2000-2016 is different from any other port; Table 8).

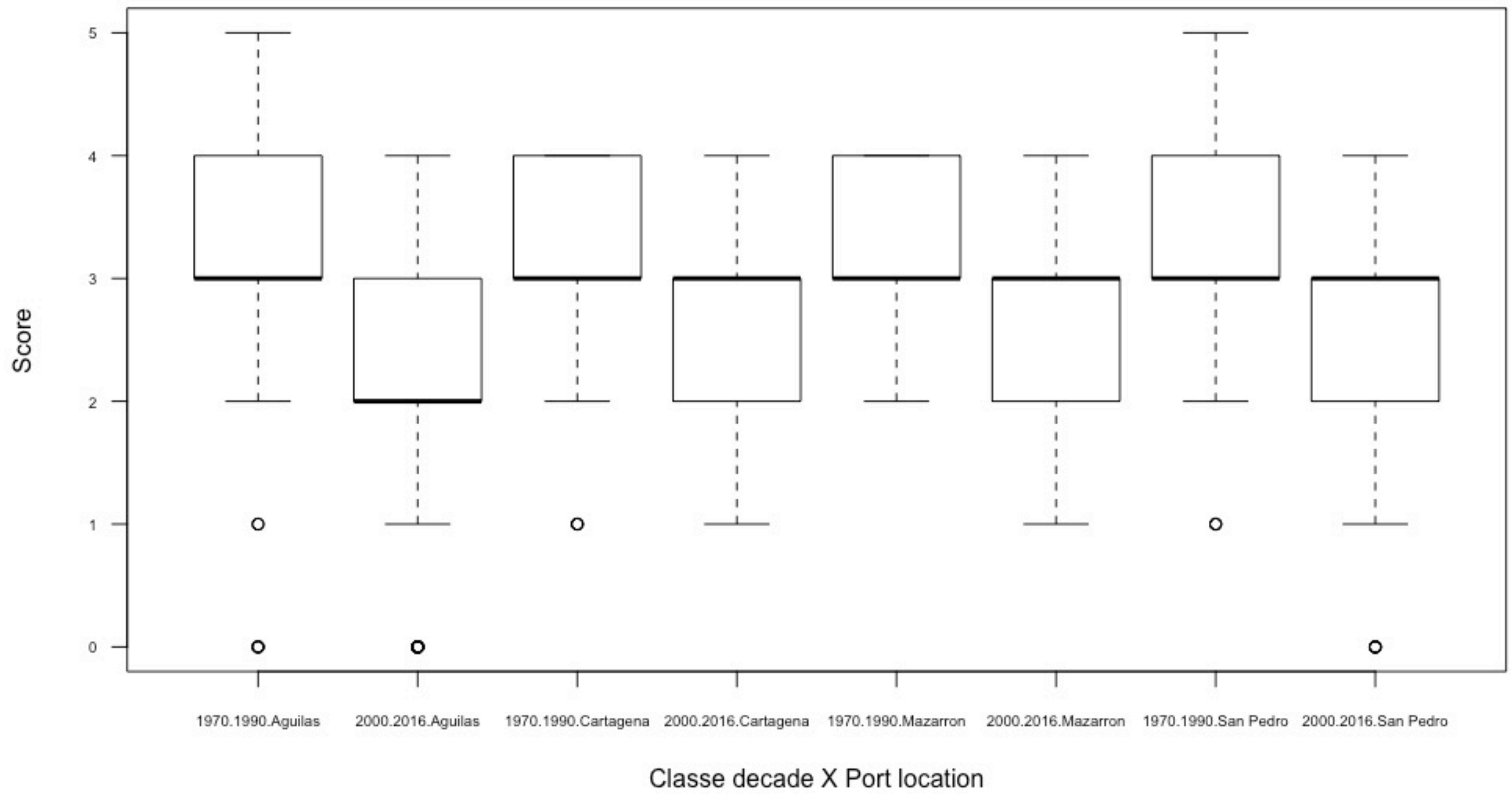


Figure 5. Boxplot of fishers scores between port (Águilas, Mazarrón, Cartagena and San Pedro del Pinatar) in each class decade (1970 to 1990 and 2000 to 2016).

Table 7. Respective sample sizes (n) for the boxplots of class decade (1970 to 1990 and 2000 to 2016) and port (Águilas, Cartagena, Mazarrón and San Pedro del Pinatar).

	Águilas	Cartagena	Mazarrón	San Pedro
1970 – 1990	212	85	46	161
2000 - 2016	267	100	87	303

Table 8. Pairwise tests of the different interactions between ports (Águilas, Mazarrón, Cartagena and San Pedro del Pinatar) and class decade (1970 to 1990 and 2000 to 2016). Statistical significance ($P < 0.05$).

	Águilas 70.90	Águilas 00.16	Mazarrón 70.90	Mazarrón 00.16	Cartagena 70.90	Cartagena 00.16	San Pedro 70.90
Águilas 00.16	**<0.0001**	-	-	-	-	-	-
Mazarrón 70.90	*ns*	**<0.0001**	-	-	-	-	-
Mazarrón 00.16	**<0.0001**	**0.0420**	**<0.0001**	-	-	-	-
Cartagena 70.90	*ns*	**<0.0001**	*ns*	**0.0013**	-	-	-
Cartagena 00.16	**<0.0001**	**0.0054**	**0.0016**	*ns*	**0.0240**	-	-
San Pedro 70.90	*ns*	**<0.0001**	*ns*	**<0.0001**	**0.0290**	**<0.0001**	-
San Pedro 00.16	**<0.0001**	**<0.0001**	**0.0170**	**0.0110**	*ns*	*ns*	**<0.0001**

Abundance scores varied with Age and 3-level Class Age (one-way PERMANOVA), and there was a significant interaction between Class Decade X Age (results not shown) but with no apparent trend observed.

According to the fishers' abundance scores, between the classes of 1970-1990 and 2000-2016 only *Zeus faber* (3.3% of all reported taxa) increased (Fig. 6). Most species (23 species, 76.7%) were identified by fishers as decreasing through time (Fig. 7). Some of these species (*Octopus vulgaris*, *Merluccius merluccius* and *Polyprion americanus*) decreased in a more evident manner (decreased in average two score points, and were reported by fishers at least five times per period). Only six species (20%) were reported by fishers as unchanged along the years (Fig. 8). Among these, *Diplodus sargus* was reported by a higher number of fishers. *Hommarus gammarus* was removed from this section due to not having entries for the class decade 1970 – 1990 and only 1 sample for the 2000 – 2016 period (n=1).

Figure 6. Boxplots of *Zeus faber* fishers scores over the two classes of time (1970 to 1990 and 2000 to 2016) of increase abundance and the respective sample size (n is the number of times a species is referred by a fisher in a total of 40 interviews).

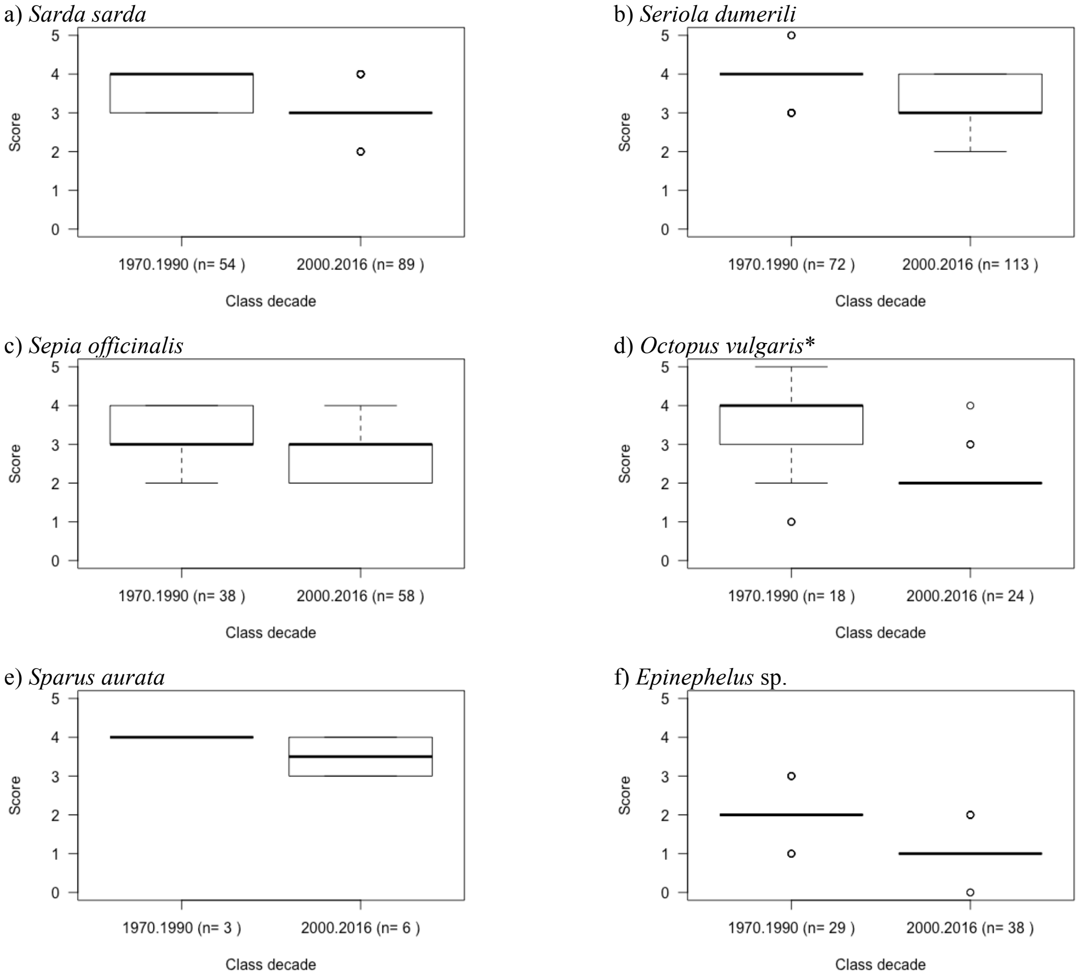
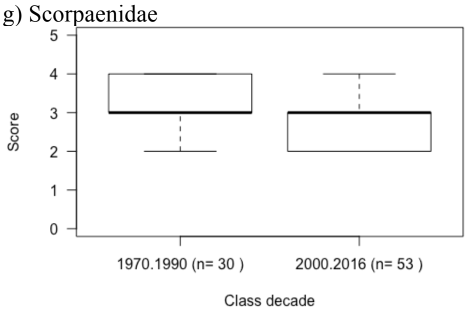
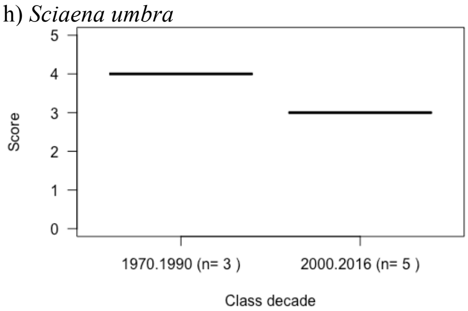


Figure 7. Boxplots of fishers' abundance scores during the two classes of time (1970 to 1990 and 2000 to 2016) for species that decreased in abundance and the respective sample size (n is the number of times a species is referred by a fisher in a total of 40 interviews). * species that have a strong decrease (change in 2 or more score points for species with n > 5).

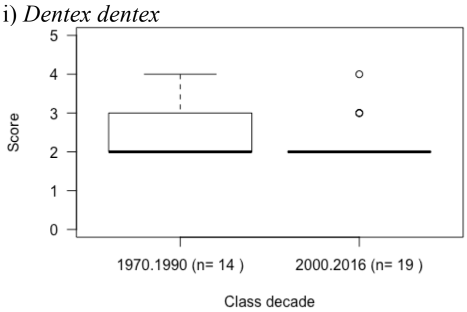
g) Scorpaenidae



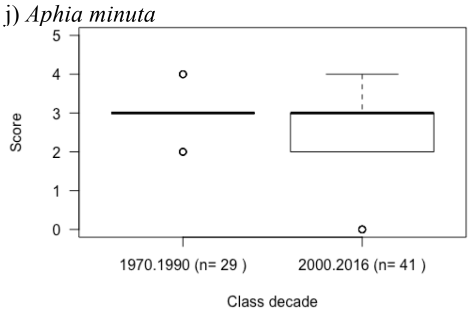
h) *Sciaena umbra*



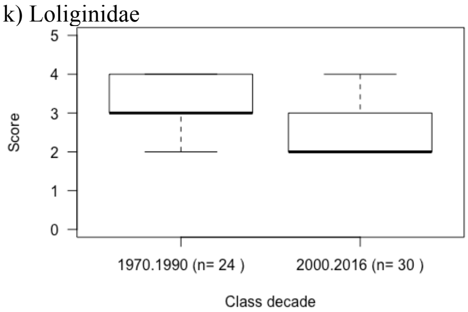
i) *Dentex dentex*



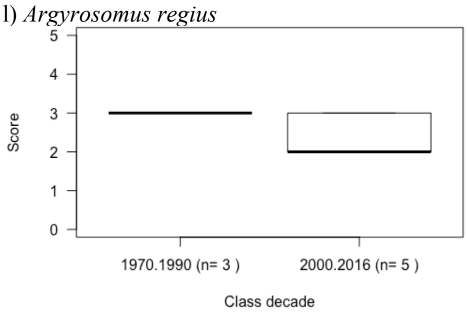
j) *Aphia minuta*



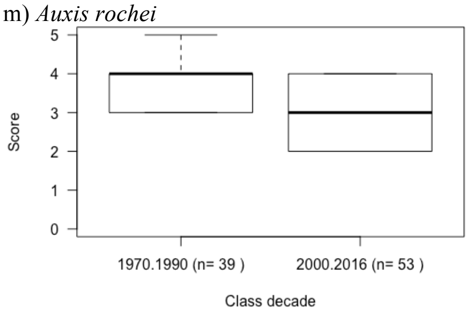
k) Loliginidae



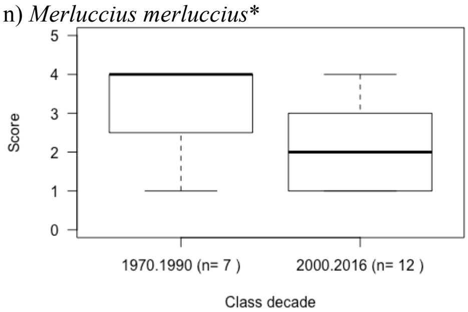
l) *Argyrosomus regius*



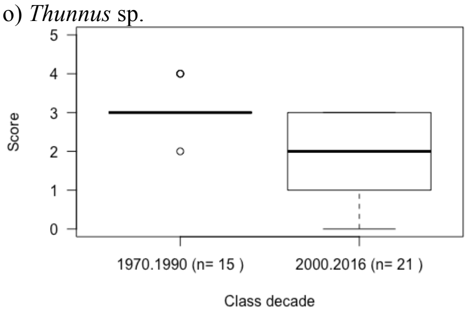
m) *Auxis rochei*



n) *Merluccius merluccius**



o) *Thunnus* sp.



p) *Pagellus bogaraveo*

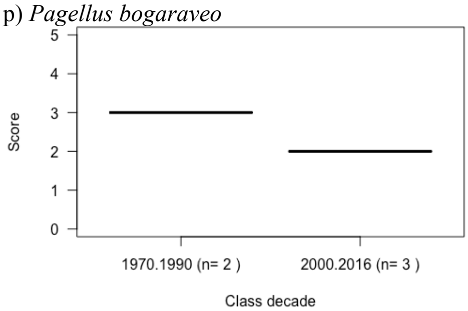
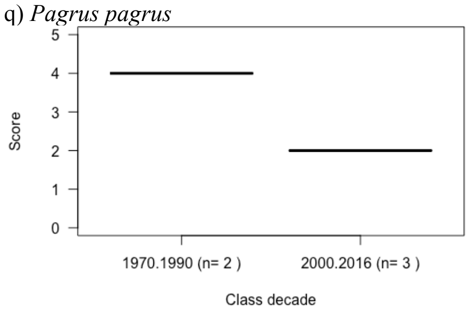
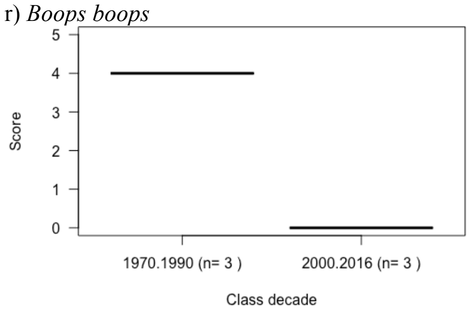


Figure 7. (continued)

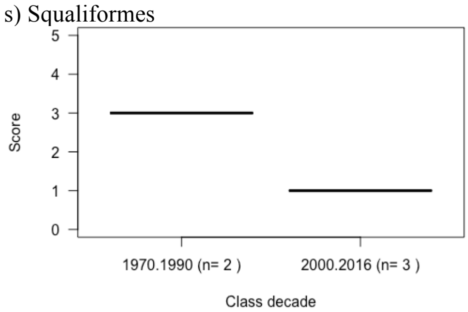
q) *Pagrus pagrus*



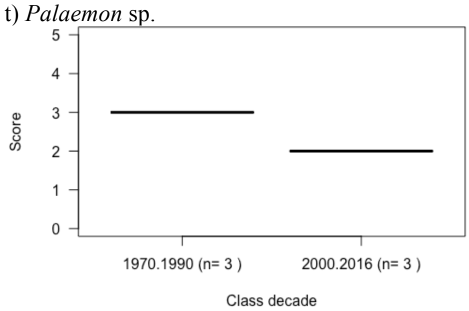
r) *Boops boops*



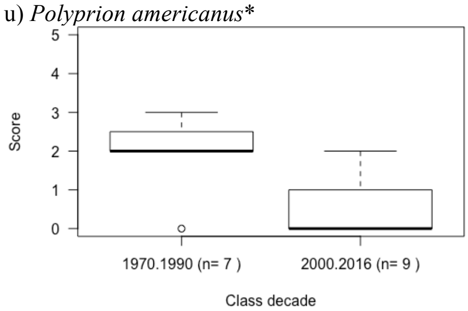
s) Squaliformes



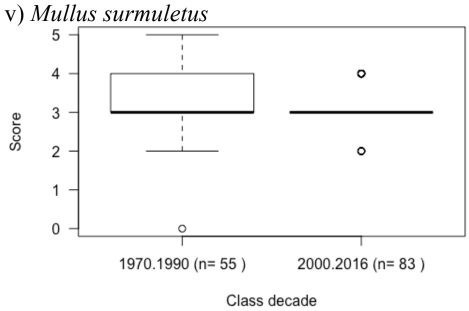
t) *Palaemon* sp.



u) *Polyprion americanus**



v) *Mullus surmuletus*



w) *Euthynnus alletteratus*

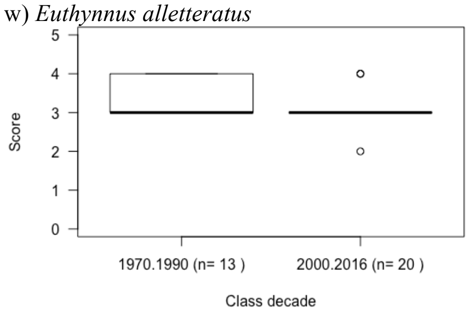


Figure 7. (continued)

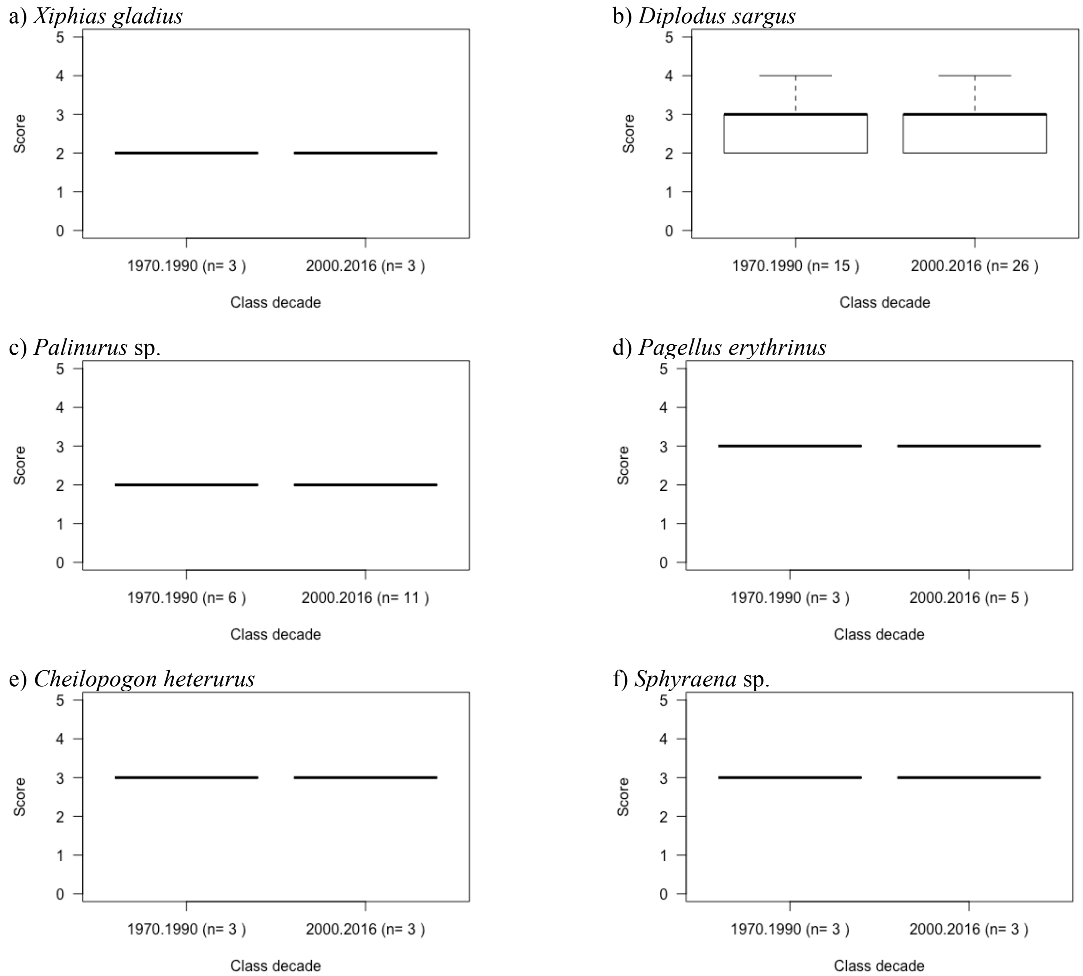


Figure 8. Boxplots of fishers' abundance scores during two classes of time (1970 to 1990 and 2000 to 2016) for species stable in abundance and the respective sample size (n is the number of times a species is referred by a fisher in a total of 40 interviews) for each class.

The SIMPER analysis shows that four species/groups of species (*Sepia officinalis*, *Auxis rochei*, Scorpaenidae and *Aphia minuta*) explain approximately 30% of the differences between the 1970 – 1990 and 2000 – 2016 decades (Table 9). These species/group of species were highlighted in the analysis because they had larger total sample sizes (n) and larger differences of sample size between class decades. Accordingly, most species of the "unchanged" group have low sample size (n) and the difference of n between class decades barely changes, therefore are in the bottom of the SIMPER analysis.

Table 9. SIMPER analysis of species that explain the dissimilarity of presence/absence between the class decade 1970 – 1990 and 2000 – 2016. The average dissimilarity of each species and the cumulative dissimilarity are represented in percentages.

Species / group of species	Average dissimilarity (%)	Cumulative dissimilarity (%)
Sepia officinalis	0.07888	0.07888
Auxis rochei	0.07887	0.15775
Scorpaenidae	0.07616	0.23391
Aphia minuta	0.07177	0.30568
Epinephelus sp.	0.06741	0.37309
Mullus surmuletus	0.06670	0.43979
Sarda sarda	0.06378	0.50357
Loliginidae	0.05892	0.56249
Octopus vulgaris	0.05077	0.61326
Diplodus sargus	0.04762	0.66088
Dentex dentex	0.04422	0.70510
Thunnus sp.	0.04391	0.74901
Euthynnus alletteratus	0.04386	0.79287
Merluccius merluccius	0.02521	0.81808
Palinurus sp.	0.02362	0.84170
Zeus faber	0.01716	0.85886
Polyprion americanus	0.01418	0.87304
Seriola dumerili	0.01369	0.88673
Sparus aurata	0.01257	0.89930
Argyrosomus regius	0.01171	0.91101
Pagellus erythrinus	0.01148	0.92249
Palaemon sp.	0.01094	0.93343
Sciaena umbra	0.01090	0.94433
Xiphias gladius	0.01087	0.95520
Cheilopogon heterurus	0.01005	0.96525
Sphyraena sp.	0.00865	0.97390
Pagellus bogaraveo	0.00574	0.97964
Squaliformes	0.00573	0.98537
Pagrus pagrus	0.00574	0.99111
Boops boops	0.00535	0.99646
Homarus gammarus	0.00354	1.00000

The PERMANOVA analysis (Table 10: Class decade) showed that the majority (92%) of traits had a significant change between the class decades of 1970 – 1990 and 2000 – 2016. The shallow (depth trait) and omnivore (diet trait) categories showed no significant change between decades. The intensity between the trend of the different traits categories (Table 10: Average Score) also varied, with 21% of slight decrease, 62% moderate decrease and 17% with a severe decrease between decades. According to fishers, fish from very deep waters, benthic habitats, make small yearly migrations or that feed on invertebrate feeders decreased the most between past decades and more recent ones.

Table 10. Results of PERMANOVA analysis of fishers' abundance score of each trait between class decades (1970-1990 and 2000-2016) and the respectively average score trend (- = slight decrease [-0.409; -0.584], -- = moderate decrease [-0.584: -0.759], --- = severe decrease [-0.759: -0.935]) and variation. Df = degrees of freedom; Pseudo-F = F value by permutation. Bold indicates statistical significance ($P < 0.05$); P-values are based on 9999 permutations.

		Class decade			Average score		
Trait	Category	Df	Pseudo-F	P-Value	1970 - 1990	2000 - 2016	Trend (variation)
Size	Small	1	15.929	**0.001**	2.868	2.182	-- (- 0.686)
	Medium	1	60.747	**0.001**	3.272	2.674	-- (- 0.598)
	Large	1	24.651	**0.001**	3.408	2.910	- (- 0.498)
	Very large	1	45.345	**0.001**	3.208	2.480	-- (- 0.728)
Depth	Shallow	1	0.0059	1.000	ns	ns	ns
	Medium	1	71.747	**0.001**	3.272	2.674	-- (- 0.598)
	Deep	1	44.109	**0.001**	3.291	2.573	-- (- 0.718)
	Very deep	1	24.689	**0.001**	2.983	2.163	--- (- 0.820)
Habitat	Pelagic	1	94.622	**0.001**	3.532	2.910	-- (- 0.622)
	Demersal	1	46.869	**0.001**	3.064	2.475	-- (- 0.589)
	Benthic	1	26.636	**0.001**	2.472	1.671	--- (- 0.801)
Schooling	Schooler	1	70.300	**0.001**	3.372	2.730	-- (- 0.642)
	Facultative schooler	1	68.339	**0.001**	2.862	2.453	- (- 0.409)
	Solitary	1	60.255	**0.001**	3.225	2.556	-- (- 0.669)
Migration	Large	1	107.810	**0.001**	3.409	2.783	-- (- 0.626)
	Medium	1	24.181	**0.001**	3.012	2.489	- (- 0.523)
	Small	1	28.227	**0.001**	2.532	1.597	--- (- 0.935)
Territorial behaviour	Territorial	1	38.995	**0.001**	2.836	2.179	-- (- 0.657)
	Non-territorial	1	109.380	**0.001**	3.403	2.792	-- (- 0.611)
Mobility	Very vagile	1	98.910	**0.001**	3.550	2.918	-- (- 0.632)
	Vagile	1	37.416	**0.001**	2.810	2.226	-- (- 0.584)
	Sedentary	1	27.574	**0.001**	3.130	2.429	-- (- 0.701)
Diet	Omnivore	1	2.910	0.118	ns	ns	ns
	Planktonivore	1	16.201	**0.001**	2.882	2.310	- (- 0.572)
	Invertebrate feeder	1	17.098	**0.001**	3.414	2.561	--- (- 0.853)
	Macrocarnivore	1	103.980	**0.001**	3.278	2.669	-- (- 0.609)

The overall pairwise test results (Tables 11 and 12) showed a significant dissimilarity (76.47%) of the trait categories between Águilas and San Pedro del Pinatar ports which are the two farthest fishing ports and showed differences in many trait categories. San Pedro del Pinatar and Cartagena showed the highest scores in the following traits: very large size, deep maximum depth, solitary behaviour, large distances yearly displacement, very vagile mobility and macrocarnivore diet.

Table 11. Results of PERMANOVA analysis of the Euclidean dissimilarities of the fisher's abundance score of each trait and category between the different ports (San Pedro del Pinatar, Cartagena, Mazarrón and Águilas) and the respectively average score and pairwise dissimilarity represented with letters (i.e. (a) is statistical different to (b) or (c) but not (a) or (ab)). Df = degrees of freedom; Pseudo-F = F value by permutation. Bold indicates statistical significance ($P < 0.05$); P-values are based on 9999 permutations.

		Port			Average port score			
Trait	Category	Df	Pseudo-F	P-value	San Pedro del Pinatar	Cartagena	Mazarrón	Águilas
Size	Small	3	1.803	0.149	-	-	-	-
	Medium	3	2.796	**0.040**	3.053 (a)	2.909 (ab)	2.972 (ab)	2.795 (b)
	Large	3	2.548	0.058	-	-	-	-
	Very large	3	11.283	**0.001**	3.012 (a)	3.032 (a)	2.712 (ab)	2.416 (b)
Depth	Shallow	2	7.146	**0.002**	3.000 (a)	2.500 (b)	-	2.000 (b)
	Medium	2	0.122	0.943	-	-	-	-
	Deep	2	6.819	**0.003**	3.176 (a)	3.020 (ab)	2.767 (ab)	2.612 (b)
	Very deep	2	1.035	0.375	-	-	-	-
Habitat	Pelagic	3	0.452	0.725	-	-	-	-
	Demersal	3	14.495	**0.001**	3.036 (a)	2.500 (b)	2.562 (b)	2.441 (b)
	Benthic	3	2.750	**0.043**	2.156 (a)	1.500 (a)	1.700 (a)	2.089 (a)
Schooling	Schooler	3	0.457	0.720	-	-	-	-
	Facultative schooler	3	3.841	**0.011**	2.798 (a)	2.467 (ab)	2.444 (ab)	2.267 (b)
	Solitary	3	7.743	**0.002**	3.066 (a)	2.873 (ab)	2.667 (ab)	2.609 (b)
Migration	Small	3	3.31	**0.024**	2.226 (a)	1.250 (b)	1.700 (ab)	2.089 (a)
	Medium	3	4.761	**0.004**	2.734 (a)	2.297 (b)	2.593 (ab)	2.923 (a)
	Large	3	12.816	**0.001**	3.210 (a)	3.218 (a)	3.046 (ab)	2.804 (b)
Territorial behaviour	Territorial	3	10.975	**0.001**	2.774 (a)	1.833 (b)	2.136 (bc)	2.324 (bc)
	Non-territorial	3	1.996	0.109	-	-	-	-
Mobility	Very vagile	3	5.788	**0.001**	3.314 (a)	3.297 (a)	3.176 (ab)	3.009 (b)
	Vagile	3	17.726	**0.001**	2.829 (a)	2.245 (b)	2.289 (b)	2.089 (b)
	Sedentary	3	4.429	**0.004**	2.600 (ab)	2.222 (b)	2.500 (ab)	2.950 (a)
Diet	Omnivore	3	4.916	**0.011**	2.689 (a)	2.000 (b)	-	2.000 (b)
	Planktonivore	3	0.943	0.428	-	-	-	-
	Invertebrate feeder	3	2.063	0.113	-	-	-	-
	Macrocarnivore	3	9.449	**0.001**	3.103 (a)	2.978 (a)	2.971(ab)	2.728 (b)

Table 12. Summary of the dissimilarity pairwise test results between the different traits (size, maximum depth, habitat, schooling behaviour, yearly displacement, territorial behaviour, mobility, diet) and ports (Águilas Cartagena, Mazarrón and San Pedro). Percentages represent overall dissimilarity and respective the sample size (n).

	San Pedro del Pinatar	Cartagena	Mazarrón	Águilas
San Pedro del Pinatar	-	-	-	-
Cartagena	41.17% (17)	-	-	-
Mazarón	20.00% (15)	0.00% (17)	-	-
Águilas	76.47% (17)	35.90% (17)	0.00% (15)	-

Discussion

The results of the present study provide new insights on how local knowledge from fishers can be used to understand how marine ecosystems, especially commercially exploited species, have changed through time. We conducted a series of questionnaires to artisanal fishers working in several fishing harbours from the region of Murcia (Spain, south-western Mediterranean), to understand how fishers perceived the changes in abundance/size of fish throughout the last four decades, and to explore differences between fishing ports. Moreover, from the results of the questionnaires we explored whether the biological and ecological traits of the fish species reported by fishers changed through time, and whether traits differed among the studied ports.

Two main results emerge from the results. First, fishers indicated a significant decrease in their fisheries catches from the decades of 1970, 1980 and 1990 to the decades of 2000 and beyond. This decrease was more pronounced in some trait categories, namely organisms that distribute down to very deep depths, are benthic, make small migrations and/or feed on invertebrates. Secondly, fishers also indicated higher fishing catches in the two northernmost ports (San Pedro del Pinatar and Cartagena) especially in some trait categories, namely organisms with very large size, that inhabit deep areas, with solitary behaviour, large yearly displacements, with very vagile mobility and/or with a macrocarnivore diet. This species-based and trait-based analysis suggests that abundances of species (and some trait categories) caught by artisanal fisheries in this region have decreased, and that either fishers in different ports target specific species (and some trait categories) or that there are different species (and some trait categories) in these ports.

The fishers' perception that catches decreased from the decades of 1970, 1980, 1990 to the decades of 2000 and beyond, is in agreement with a decrease in fisheries landings in this region. In the region of Balearic division of the western Mediterranean sub area (of FAO major fishing areas), Coll et al. 2015 showed that the landings increased from 1950 to the 1960s and declined from the 1970s to 2010, based on FAO data. However, according to the same study, reconstructed total catches after accounting for all fisheries removals (i.e. unreported landings and discards) revealed that landings had an earlier maximum in the late 1950s, stabilized during the 1960s and 1970s, and declined from the early 1980s to 2010 (Coll et al. 2015). Overfishing is the possible cause of this decrease since fishing effort and capacity increased from the 1960s to 2015 and consequently CPUE decreased (Coll et al. 2008, 2015). The consequences of overfishing are not only ecological, since they diminish the ecosystems resistance (ability to withstand changes) and resilience (ability to recover from those changes; Boyes et al. 2015) but also socio-economic (Kent 1986, Christensen et al. 1996). Besides the local loss of biodiversity, the decrease in fish abundance, mainly predators, affects food webs through changes in top-down control of abundance and size of preyed species (Hutchings & Baum 2005, Heithaus et al. 2008). Regarding socio-economic aspects, overfishing collapses local fisheries due to the decrease in abundance of commercial fish, implying for instance the need for stricter fisheries restrictions to control decline of resource abundance and affected jobs (Hilborn 2007). Regarding the political and social aspects, fishers are also directly affected since their revenue decreased (due to lower catches) and may partially dependent on government subsidies (Sumaila & Pauly 2006). Throughout history multiple species have become overfished with both ecological and economic implications namely the collapse of Peruvian anchovy (Clark 1976), Californian herring (Pauly et al. 2001) and Atlantic cod (Hutchings & Myers 1994). In the western Mediterranean, 96% of stocks are overfished (European Comission 2015) and fishing above the maximum sustainable yield persists while 20% of species are still data deficient on their level of threat (Fernandes et al. 2017). This lower catches of species in more recent decades might be related to overexploitation of fish stocks, pollution and habitat degradation that persist in the Mediterranean Sea (Coll et al. 2010). These impacts are mostly created by coastal modification, maritime traffic and bottom trawlers which change coastal benthic habitats affecting fish abundance, and hence marine biodiversity, by diminishing the availability of refuges, food availability and nursery grounds of certain species (Turner et al. 1999, Coll et al. 2012). Regarding habitat degradation, the Mediterranean has been mentioned as a sensitive and exposed environment for eutrophication, due to its enclosed geography and nutrient rich water basin discharges (Karydis & Kitsiou 2012). For instance, in the coast of Murcia, since the 1990s, pollution of the Mar Menor coastal lagoon due to eutrophication (Velasco et al. 2006) and urban development (Perez-Ruzafa et al. 1991) in the San Pedro del Pinatar area have consequences to this coastal ecosystem that plays an important role for various fish species (i.e. nursery, feeding and refuge) which also integrates coastal assemblages and fisheries stocks (Pérez-Ruzafa et al. 2006). Finally and more recently, the rising of non-indigenous species in Mediterranean waters is seen as one of the fast growing threats to local marine ecosystems (Coll et al. 2010). Namely, through the recently-expanded Suez Canal in the eastern Mediterranean (Galil et al. 2014) that increases maritime transportation and Lessepsian migration (species migrations through the Suez Canal; Gollasch 2006), and the Gibraltar strait in the western Mediterranean due to global rising water temperatures and shifts in range of tropical species to sub-tropical areas (Occhipinti-Ambrogi & Galil 2010). Non-indigenous species impact ecosystems at species and community levels, changing local biodiversity and may become impossible to revert (Grosholz 2002, Katsanevakis et al. 2016).

The interviewed fishers reported 31 taxa (22 species, six genera, two families and one order). Most of the taxa (23) were reported to decrease in abundance throughout the study decades (1970s-2016), especially before and after 2000s. Some of the recorded taxa (*Merluccius merluccius*, *Octopus vulgaris* and *Polyprion americanus*) had more marked decreases. In contrast, fishers reported *Zeus faber* as the only species that increased in captures. *Merluccius merluccius* is overexploited since 1990s (Lleonart & Maynou 2003) and continues to be exploited above the maximum sustainable yield (MSY) levels in the western Mediterranean Sea (Fernandes et al. 2017), which seems to align well with the results of this study. *Octopus vulgaris* is commonly caught in the Mediterranean including the Spanish eastern coast, with important landings by trawl and small scale fisheries (Quetglas et al. 2015), and it is in GFCM stock assessment priority list (General Fisheries Commission for the Mediterranean (GFCM) 2017). Although most Mediterranean stocks of octopus are not assessed, the decrease in catches of this species (Quetglas et al. 2015) and overall of all marine molluscs (Insituto Nacional de Estadística, 2017) from the 1990s to 2000s due to intensive fishing in the Balearic region since the 1970s might indicate the overexploitation of local stocks (also described in Quetglas et al. 2015). Contrarily a decrease in demand of this species as a target species comparatively to other taxa could also take place. However, at a global scale, Doubleday et al. 2016 suggest an increase of cephalopods in both fisheries catches and survey data. This growth is mainly attributed to fishing, by releasing predation of higher ranks and competition pressure and ocean warming (Doubleday et al. 2016) since cephalopods life cycles are accelerated by warmer waters (Pierce et al. 2008). Climate change is one of the major growing problems of the Mediterranean sea (Coll et al. 2010) since rising of water temperatures and decreases in precipitation rates is expected in the Mediterranean region, specially in its north-western part (Giorgi & Lionello 2008). The decrease of *Octopus vulgaris* could be related to lower fishing interest in this species when compared to the increasing effect of warming. Still a precautionary approach in molluscs fisheries management should be adopted (Rodhouse et al. 2014). As for *Polyprion americanus,* Ball et al. 2000 suggested that north and west Atlantic and Mediterranean stocks are genetically similar and should be threated together. Despite few stock assessments have been undertaken for this species, some populations decreased in the 1980s and 1990s and strong measures for sustainable fisheries entered into force (South Atlantic Fishery Managment Council 1991). Although it is still data deficient, in 2015 the International Union for Conservation of Nature (IUCN) highlighted that stocks of this species are expected to continue to decline if fishing is not controlled, due to high captures and commercial value (Sedberry et al. 1999) and reproduction biology with late maturity (9 - 15 years; Peres & Klippel 2003).

In addition to considering taxonomic changes of catches through time as perceived by fishers, we also considered changes in functional aspects. A trait-based approach can be helpful to understand distribution of species over time and space, and their respective drivers of change (biotic and abiotic drivers; Violle, Reich, Pacala, Enquist, & Kattge, 2014). Furthermore, it can help to understand ecosystem functioning (Fisher et al. 2010) and comprehend their response in global environmental changes (Litchman & Klausmeier 2008, Henriques et al. 2017). But while trait-based approaches have been quite developed in marine ecosystems, knowledge of the links between species traits and marine ecosystem functioning are not as developed (e.g. Lavorel & Garnier 2002, McGill et al. 2006). The results of questionnaires and the characterization of functional traits, showed that all considered functional trait categories decreased from the earlier to the later decades but some trait categories decreased more severely, namely organisms: that distribute down to very deep depths, are benthic, migrate (yearly) over small distances and/or feed on invertebrates (Table 5). These results indicate that abundance of species with some traits decreased. But this is not representative of the whole community since not all of it is fished. In general, different species could be exposed to human pressures (i.e. fishing, pollution, habitat degradation, climate change) depending on their life traits (Perry 2005, Diaz Pauli & Sih 2017). For example, non-migrant or small distance (yearly) migratory species have a reduced capacity to occupy other patches (Pitcher 1995). Since these species are confined to small areas, when confronted with environmental changes they are less likely to succeed compared to those who have a more dispersal potential which makes them less resistance to human pressures (Reynolds et al. 2005). Invertebrate feeders have a medium trophic level and feed mainly on small benthic invertebrates (despite also consuming some algae and fish; Stergiou & Karpouzi 2001). It is known that physical disturbances (e.g. bottom trawling which removes individuals, changes substrate and causes turbidity) can change benthic invertebrate communities (Palanques et al. 2001, Tudela 2004) and eutrophication (which increase primary productivity but can cause hypoxia and harmful algal blooms; Karydis & Kitsiou 2012) can lead to trophic and communities changes. But a possible link between different types of disturbance (overfishing, habitat degradation, eutrophication) and observed invertebrate feeders is yet to be explored. In addition, a process of "fishing down marine food webs" may have resulted in an earlier decrease of species with higher trophic levels / larger sizes / higher mobility (not reported by fishers in these questionnaires) but a more recent decline in lower trophic levels (possibly already reported by fishers in the questionnaires; Pauly 1998). This hypothesis also remains to be further explored. In general, changes within food webs can have other complex consequences within ecosystems due to trophic interactions, which can result in changes in ecosystems functioning and services (Worm et al. 2006, Narayanaswamy et al. 2013).

Artisanal fisheries are widely considered sustainable due to their gear specificity, catch diversification throughout the year and lower catches (Guyader et al. 2013), but they can become unsustainable if not regulated and managed (i.e. total allowable catch quotas, mesh size restrictions, bycatch quotas, gear modifications to reduce bycatch; Roberts et al. 2005, Castello et al. 2011). Although Europe successfully reduced fishing effort in the Northeast Atlantic (Fernandes & Cook 2013), overfishing in the Mediterranean Sea is leading to the exploitation of demersal and benthic fish populations (Fernandes et al. 2017) and a degradation of the benthic communities (Tillin et al. 2006, De Juan Mohan & Demestre 2007). Artisanal fisheries also account for these pressures since many technological improvements (i.e. echo sonar, introduction and increase of engine power) allowed fishers to fish farther and in deeper waters (Colloca et al. 2003).

Moreover, perceived catches of each trait category varied significantly between ports, with values of several of traits categories differing between the two more northern and the more southern ports: very large size, deep maximum depth, solitary behaviour, large distance migratory, very vagile and macrocarnivore diet. In the study area, there is a MPA (Cabo de Palos – Islas Hormigas marine reserve) with a no-take area of ≈ 3 km^2 and a buffer zone of ≈ 16 km^2, between the two northern ports. This marine reserve was established mainly to support local artisanal fisheries and has been proven effective in both protecting the local ecosystem and commercial fish species from human impacts, while local artisanal fisheries in the buffer zone increased their catches (García-Charton et al. 2015) and spill-over effect to nearby areas occurred beyond the buffer zone (Goñi et al. 2008). The questionnaire implemented in the present study identified higher perceived catches in these two more northern ports in general and especially for some functional traits, indicating those associated with species having responded to protection measures. Throughout the world, the importance of no-take marine protected areas to local and artisanal fisheries has been supported namely through demonstration of positive effects of spill-over. Positive effects on MPA are generally favoured by compliance and enforcement (Edgar et al. 2014, Di Franco et al. 2016), existence of no-take areas (Claudet et al. 2010, Edgar et al. 2014), large sized areas, higher age since establishment (Claudet et al. 2008) and management plans that integrate fishers communities (specially for small scale fisheries; Di Franco et al. 2016). Compliance and enforcement (Samoilys et al. 2007, Guidetti et al. 2008), and no-take areas (Vandeperre et al. 2011) reduce some human pressures (e.g. fisheries) on communities within MPAs. In addition, larger size of the MPA promotes the protection of vagile species (Edgar et al. 2014), while older MPAs favour large body sized species which have later maturity, and larger more fecund individuals (Roff 1984, Claudet et al. 2008). The Cabo de Palos – Islas Hormigas marine reserve has 22 years of establishment (Consejero de Agricultura Ganadería y Pesca 1995) and evidence of adult spill-over and pelagic eggs/larvae dispersal to outside the reserve has been reported (García-Charton et al. 2008, Goñi et al. 2008). Our results seem to fit with a spill-over effect since very large sized and deep maximum range (which covary; Stefanescu et al. 1992), large distance yearly migrations, and macrocarnivore trait categories (Romanuk et al. 2011) were more abundant in the northern ports, i.e. around the MPA. Monitoring studies of the Cabo de Palos – Islas Hormigas marines reserve, have pointed to a global increase in catches of large fish species in both the buffer zone and other farther local fishing grounds (García-Charton et al. 2015). To better understand the spill-over effectiveness of this reserve, more research on migration of large commercial fish species or larval/egg dispersion should be made. Conversely, differences in species catches between the north and south areas can be due to habitat, but may be less important since geographical/environmental contrast is more noticeable between the northern most port (north of Cabo de Palos) and the three ports south of the cape. Moreover, fishing tactics and gears used are similar among ports (Forcada et al. 2010). Environmental factors, such as habitat type and complexity, are fundamental aspects that define the abundance, structure and diversity of fish assemblages in marine ecosystems (St. Pierre & Kovalenko 2014). In this scope, complex habitats (i.e. complex rocky reefs) like those of Cabo de Palos (Garcia-Charton et al. 2004), promote species richness and abundance of fish species through increase surface area, resource and refuge availability (Charton & Ruzafa 1998). This may help explain the higher abundance of some trait categories in the northern ports (around Cabo de Palos; i.e. solitary species). However, direct comparisons of habitats among the studied areas are still needed. Furthermore, abiotic conditions seem similar among study ports: sea surface temperature (Giovanni, NASA – MODIS Aqua, 2017; 19-20ºC from 2014-2016) and chlorophyll a level (Giovanni, NASA – SeaWiFS, 2017; 0.6 mg m^{-3} from 2007-2010 but 0.8 mg m^{-3} in the southern port of Águilas). These are mainly attributed to input of nutrient-rich Atlantic superficial (less dense) water mass from the Gibraltar strait and upwelling caused by gyres induced by water masses mixtures (Atlantic and Mediterranean Estrada 1996). Garcia-Charton et al. (2004) attribute the higher richness and abundance of fish assemblages in the Águilas coastal area to its higher primary productivity (compared to Cabo de Palos). Another aspect that might influence functional differences between north and south ports is the Mar Menor coastal lagoon next to the northern port of San Pedro del Pinatar, important for both nutrient supply and nursery ground, although heavily impacted due to coastal degradation and tourism (Pérez-Ruzafa et al. 2006).

The lack of historical data (i.e. landings and stock assessment) limits our understanding of trends in local fisheries (Daw 2010). This limitation highlights the interest in using local knowledge. There are however some constrains to this approach, which could lead to the definition of false baselines: e.g. personal amnesia (changes in the perception of normal over the decades; Papworth et al. 2009) or memory illusion (exaggerate or lessen catches in a specific year/decade; Daw 2010). To minimize this problem, the structure of the questionnaire and the interviews should follow recommended guidelines ethical and technical procedures (Bunce et al. 2000). In the present study, we followed some of these guidelines, such as random or snowball sampling techniques to interview most of the fish community, fish guides and photographs with common and scientific names, and local species guides to better identify the species. Despite this, however, local knowledge information should be interpreted carefully due to the potential biases above mentioned.

The results of the present study seem to support the possibility of identifying general temporal and spatial changes in catches throughout decades based on local knowledge. This possibility is especially valuable for data deficient regions or countries where landing, stock assessment or monitoring data are absent or insufficient. Previous studies reported that fishers perceptions can be used to unveil past fish abundances in other regions (Sáenz-Arroyo et al. 2005, Lozano-Montes et al. 2008), including the Mediterranean Sea (Azzurro et al. 2011, Maynou et al. 2011, Coll et al. 2014). Briefly, our study supports a decrease of artisanal fisheries catches among decades in the coast of the region of Murcia (south-western Mediterranean), and that that this decrease was more marked for species with some biological traits. Moreover, our study also indicates higher artisanal fisheries catches in the northern port, especially for species harbouring some traits that are especially favoured around MPAs. However, further work must be made to validate the results of questionnaires and to better understand changes of local artisanal fishing habits throughout decades (and its causes). To validate our approach based on fishers' perception, monitoring data of species and habitats (e.g. visual census, landings, fisheries observations, survey data) is needed to compare areas and to follow changes through time. Further development of this approach can help better understand how local catches vary in time and space and how relevant they are to support the provisioning of ecosystems services.

Final Remarks

To better understand current and future status of marine ecosystems, we need to better understand their past. In this context, data on past state of marine ecosystems becomes highly valuable. Local ecological knowledge from fishers can be important since they can provide unique and useful data about past and present fishing effort, catches and bycatch (and eventually on illegal, unreported and unregulated fishing; Coll et al. 2015). Complementing local ecological knowledge data with stock assessment surveys and official landings can provide new insights into the dynamics of fished populations since these procedures combine different types of information.

Multiple management tools are commonly made to achieve sustainable fisheries and avoid further damage of marine ecosystems, such as improving gear selectivity, closed fishing seasons and areas and marine protected areas. In particular, marine protected areas have been established in many regions worldwide as conservation strategies to avoid certain human activities like fishing and coastal alterations (Halpern 2003). In addition, marine protected areas can promote spill-over effects that will replenish surrounding stocks and benefit surrounding fisheries (Goñi et al. 2008, Di Lorenzo et al. 2016). Although the establishment of MPAs is known to protect fished species and promote an increase in biomass, its success depends on several features (e.g. enforcement, size, age of establishment; Edgar et al. 2014, Guidetti et al. 2014). However, effects of MPAs on other important aspects of ecosystems have not been sufficiently considered for instance as effect on different dimensions of biodiversity other than species, namely phylogenetic and functional aspects (Guilhaumon et al. 2015). In this context, improving the success of marine protected areas in reducing biodiversity loss for instance in the Mediterranean Sea could potentially benefit from: the establishment of protected area networks that comprehend the majority of the life history stages of protected species and the functions that they play in the ecosystem (Di Franco et al. 2012, Guilhaumon et al. 2015), a better protection of these species against fisheries pressure (Roberts 2003) and an increased protection of rarely considered habitats (i.e. deep sea; Abdulla, Gomei, Hyrenbach, Notarbartolo-di-Sciara, & Agardy, 2008).

Understanding changes in marine ecosystems through time requires the comparison to previous conditions. In this context, an environmental baseline represents a reference point against which comparisons are made and must be established when implementing protection and conservation measures in marine ecosystems, or other (Gatti et al. 2015). But long-term scientific data about marine ecosystems status is in most cases scarce or absent especially about ancient conditions (Jackson et al. 2001, Knowlton & Jackson 2008), whereas the marine environment has undergone millennia of human impacts and especially centuries of industrialization). Because of this lack of data, scientific community need to resort and adapt other sources of information (i.e. logbooks, ancient trade documents and local ecological knowledge) to reconstruct past environment and ecosystems aiming at establishing true baselines (Lotze & Worm 2009, Maynou et al. 2011). Despite associated error, such data may be key for establishing baselines for scientific assessments (Pauly 2010). In this scope, a local ecological knowledge approach namely via gathering information about marine ecosystems through interviews to fishers is ideal to provide new insights on past species abundances, exploitation rates and habitats (Rasalato et al. 2010, Coll et al. 2014).

The need for data and studies on the marine environment is urgent since the exploitation of marine resources and habitat degradation is continuing at a fast rate (Coll et al. 2010, Fernandes et al. 2017). Regarding fisheries, studies depend largely on surveys for stock assessments that estimate the spawning stock biomass and age/size distribution, and official landings (Cardinale & Svedäng 2008). Nevertheless, illegal unreported and unregulated catches can be very abundant but are mostly not accounted for, which leads to an underestimation of fisheries landings (Coll et al. 2015). Since these official fisheries landings are used for the establishment of quotas, and do not adequately account for discards or unreported catches (Pauly et al. 2014), underestimated catches can lead to inadequate fisheries management and conservation of exploited species (Daw & Gray 2005). Therefore, aiming at a better estimation of bycatch, discards and illegal unreported and unregulated catches, further work on fisheries catches and impacts must be made, for instance through independent on-board observation programs (FAO 2002, López et al. 2003, Megalofonou et al. 2005). Moreover, stock assessment surveys and management models that take into account discards and illegal unreported and unregulated catches, need to be improved to deal with data deficient species which is a relevant situation in the Mediterranean Sea (FAO 2002, Fernandes et al. 2017).

In addition to the impacts of fishing, the Mediterranean Sea is under multiple anthropogenic pressures and environmental changes that have been contributed to loss and degradation of its habitats and biodiversity (Coll et al. 2012). Climate change has been pointed out as a major increasing concern in the Mediterranean Sea (Giorgi & Lionello 2008, Coll et al. 2010), since for instance, higher water temperatures increase the opportunity of establishment of new non-indigenous species after entering the Mediterranean (through the Suez canal and Gibraltar strait; Raitsos et al., 2010). To understand effects of climate change on marine ecosystems and fisheries stocks, we need to study the magnitude of climate change impact on the species (e.g. temperature influence on life history traits; (Doubleday et al. 2016) and ecosystem levels (bottom-up and top-down effects in food webs; Lejeusne et al. 2010). Habitat loss and degradation (including water quality; Lenihan & Peterson 1998), especially due to eutrophication and coastal modification, are also major threats in the Mediterranean region (Coll et al. 2010). In the studied region (i.e. Murcia), western Mediterranean, eutrophication (from nutrient rich runoff) and coastal modification (urban development and tourism pressure; Pérez-Ruzafa et al., 2006) have been growing and have for instance led to degradation of a 170 km2 of Ramsar Convention listed coastal lagoon (Velasco et al. 2006). Since coastal lagoons perform important functions (e.g. nursery, food provision, refuge), certain life history stages (especially juveniles) are impacted and may compromise local fisheries (Pérez-Ruzafa et al. 2006). Furthermore, understanding the wider consequences of these impacts on different life history stages and on ecological networks (i.e. food webs) is crucial to provide insight on how they affect ecosystems services like the provision of food and capacity to maintain water quality (Perez-Ruzafa et al. 2002).

To improve the understanding of changes of marine ecosystems in the study area, further work is needed. For instance, it would be important to validate the questionnaire data obtained in the present study against data from monitoring surveys and/or official landings for the same ports/fishing grounds of those ports. This would allow to evaluate the accuracy of the information given by fishers during the years for which there are other data. Moreover, it would be highly valuable to better investigate in and around the Cabo de Palos – Islas Hormigas marine reserve some of the hypotheses that we propose in the present study, such as spillover effect from the marine protected area to nearby ports (located north) especially on species with some traits (maximum size, very vagile, benthic, and bentho-pelagic; Claudet et al. 2010).

The present study was based on questionnaires to artisanal fishers, hence it focused only on a part of the biological communities from this marine ecosystem (fish and invertebrate species that are caught by this type of fishing and that have commercial value). Therefore, our approach does not address all effects of fishing on marine ecosystems, namely indirect effects such as habitat degradation and cascading effect through food webs caused by predator removal. Studies that include the fish community and/or investigate the relationship between fishing pressure and these indirect impacts should be made to complement the obtained data (Travis et al. 2014). Lastly, the accumulation of impacts from fishing and from recent increasing pressures in the Mediterranean Sea (i.e. climate change and introduction of non-indigenous species) may cause fish communities to be more susceptive to decline and decrease the ecosystems ability to recover from other impacts (Micheli et al. 2012). Therefore, understanding the impacts that fisheries and other activities/pressures can trigger on fish communities, including their interactive and synergistic effects, could be useful when managing fisheries.

In all, although we know in part what and how much human societies fish and the status of exploited stocks (FAO 2005, 2016a), data on past decades is scarce and hard to acquire in order to establish environmental baselines (Lozano-Montes et al. 2008). Baselines are crucial to protect marine biodiversity through comparison of past states and therefore act to minimize human impacts on marine ecosystems (Coll et al. 2014). Although some impacts are identified and persist in the marine environment (e.g. fishing, habitat degradation, pollution) others are increasing (i.e. climate change, introduction of non-indigenous species; Coll et al., 2010). Further research aiming at understanding how these impacts affect the marine environment and at identifying shifting baselines (Pauly 1995) is needed to better manage human activities, reduce their impacts and protect current biodiversity ensuring a sustainable use of marine ecosystems.

References

Abaunza P, Fariña AC, Murta A (2003) Applying biomass dynamic models to the southern horse mackerel stock (Atlantic waters of Iberian Peninsula). A comparison with VPA-based methods. Sci Mar 67:291–300

Abdulla A, Gomei M, Hyrenbach D, Notarbartolo-di-Sciara G, Agardy T (2008) Challenges facing a network of representative marine protected areas in the Mediterranean: prioritizing the protection of underrepresented habitats. ICES J Mar Sci 66:22–28

Agnew DJ, Pearce J, Pramod G, Peatman T, Watson R, Beddington JR, Pitcher TJ (2009) Estimating the Worldwide Extent of Illegal Fishing (SA Sandin, Ed.). PLoS One 4:e4570

Anderson MJ (2001) A new method for non-parametric multivariate analysis of variance. Austral Ecol 26:32–46

Anderson MJ, Gorley RN, Clarke RK (2008) Permanova+ for Primer : guide to software and statisticl methods. PRIMER-E, Plymouth, UK

Attiwill P (1983) Physiological Plant Ecology IV (OL Lange, PS Nobel, CB Osmond, and H Ziegler, Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg

Azzurro E, Moschella P, Maynou F (2011) Tracking signals of change in mediterranean fish diversity based on local ecological knowledge. PLoS One 6:1–8

Ball AO, Sedberry GR, Zatcoff MS, Chapman RW, Carlin JL (2000) Population structure of the wreckfish Polyprion americanus determined with microsatellite genetic markers. Mar Biol 137:1077–1090

Bastari A, Micheli F, Ferretti F, Pusceddu A, Cerrano C (2016) Large marine protected areas (LMPAs) in the Mediterranean Sea: The opportunity of the Adriatic Sea. Mar Policy 68:165–177

Beck M, Airoldi L (2007) Loss, Status and Trends for Coastal Marine Habitats of Europe. In: Oceanography and Marine Biology: An Annual Review.p 345–405

Bender MG, Floeter SR, Hanazaki N (2013) Do traditional fishers recognise reef fish species declines? Shifting environmental baselines in Eastern Brazil. Fish Manag Ecol 20:58–67

Boyes S, Murillas-Maza A, C. Uyarra M, Eronat H, C. Bizsel K, Kaboglu G, Papadopoulou N, Hoepffner N, Patrício J, Kryvenko O, Churilova T, Newton A, Oinonen S (2015) Key Barriers of Achieving Good Environmental Status (GES).

Bunce M, Rodwell LD, Gibb R, Mee L (2008) Shifting baselines in fishers' perceptions of island reef fishery degradation. Ocean Coast Manag 51:285–302

Bunce L, Townsley P, Pomeroy R, Pollnac R, Cesar H, Nicholson E, Wiley P (2000) Socioeconomic Manual for Coral Reef Management. Townsville

Cacaud P (2005) Fisheries laws and regulations in the Mediterranean: a comparative study. FAO, Rome

Cadrin SX, Dickey-Collas M (2015) Stock assessment methods for sustainable fisheries. ICES J Mar Sci 72:1–6

Cardinale M, Charef A, Chato Osio G (Eds) (2013) Scientific, Technical and Economic Committee for Fisheries (STECF) – 2013 Assessment of Mediterranean Sea stocks part I (STECF 13-22). Publications Office of the European Union, Luxembourg

Cardinale M, Svedäng H (2008) Mismanagement of fisheries: Policy or science? Fish Res 93:244–247

Carvalho N, Edwards-Jones G, Isidro E (2011) Defining scale in fisheries: Small versus large-scale fishing operations in the Azores. Fish Res 109:360–369

Castello L, McGrath DG, Beck PSA (2011) Resource sustainability in small-scale fisheries in the Lower Amazon floodplains. Fish Res 110:356–364

CBD (2013) Quick guides to the Aichi Biodiversity Targets.

Charton J a G, Ruzafa a P (1998) Correlation Between Habitat Structure and a Rocky Reef Fish Assemblage in the Southwest Mediterranean. Mar Ecol 19:111–128

Charton JAG, Ruzafa ÁP (1999) Ecological heterogeneity and the evaluation of the effects of marine reserves. Fish Res 42:1–20

Cheung WWL, Lam VWY, Sarmiento JL, Kearney K, Watson R, Pauly D (2009) Projecting global marine biodiversity impacts under climate change scenarios. Fish Fish 10:235–251

Christensen NL, Bartuska AM, Brown JH, Carpenter S, D'Antonio C, Francis R, Franklin JF, MacMahon JA, Noss RF, Parsons DJ, Peterson CH, Turner MG, Woodmansee RG (1996) The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem

Management. Ecol Appl 6:665–691
Clark WG (1976) THE LESSONS OF THE PERUVIAN ANCHOVETA FISHERY. Rome
Claudet J, Osenberg CW, Benedetti-Cecchi L, Domenici P, García-Charton JA, Pérez-Ruzafa Á, Badalamenti F, Bayle-Sempere J, Brito A, Bulleri F, Culioli JM, Dimech M, Falcón JM, Guala I, Milazzo M, Sánchez-Meca J, Somerfield PJ, Stobart B, Vandeperre F, Valle C, Planes S (2008) Marine reserves: Size and age do matter. Ecol Lett 11:481–489
Claudet J, Osenberg CW, Domenici P, Badalamenti F, Milazzo M, Falcón JM, Bertocci I, Benedetti-Cecchi L, García-Charton J-A, Goñi R, Borg JA, Forcada A, Lucia GA de, Pérez-Ruzafa Á, Afonso P, Brito A, Guala I, Diréach L Le, Sanchez-Jerez P, Somerfield PJ, Planes S (2010) Marine reserves: Fish life history and ecological traits matter. Ecol Appl 20:830–839
Coll M, Carreras M, Ciércoles C, Cornax M-J, Gorelli G, Morote E, Sáez R (2014) Assessing Fishing and Marine Biodiversity Changes Using Fishers' Perceptions: The Spanish Mediterranean and Gulf of Cadiz Case Study (KI Stergiou, Ed.). PLoS One 9:e85670
Coll M, Carreras M, Cornax M-J, Massutí E, Morote E, Pastor X, Quetglas A, Sáez R, Silva L, Sobrino I, Torres M, Tudela S, Harper S, Zeller D, Pauly D (2015) An estimate of the total catch in the Spanish Mediterranean Sea and Gulf of Cadiz regions (1950-2010). Univ Br Columbia:1–29
Coll M, Palomera I, Tudela S, Dowd M (2008) Food-web dynamics in the South Catalan Sea ecosystem (NW Mediterranean) for 1978-2003. Ecol Modell 217:95–116
Coll M, Piroddi C, Albouy C, Rais Lasram F Ben, Cheung WWL, Christensen V, Karpouzi VS, Guilhaumon F, Mouillot D, Paleczny M, Palomares ML, Steenbeek J, Trujillo P, Watson R, Pauly D (2012) The Mediterranean Sea under siege: Spatial overlap between marine biodiversity, cumulative threats and marine reserves. Glob Ecol Biogeogr 21:465–480
Coll M, Piroddi C, Steenbeek J, Kaschner K, Rais Lasram F Ben, Aguzzi J, Ballesteros E, Bianchi CN, Corbera J, Dailianis T, Danovaro R, Estrada M, Froglia C, Galil BS, Gasol JM, Gertwagen R, Gil J, Guilhaumon F, Kesner-Reyes K, Kitsos M-S, Koukouras A, Lampadariou N, Laxamana E, López-Fé de la Cuadra CM, Lotze HK, Martin D, Mouillot D, Oro D, Raicevich S, Rius-Barile J, Saiz-Salinas JI, San Vicente C, Somot S, Templado J, Turon X, Vafidis D, Villanueva R, Voultsiadou E (2010) The Biodiversity of the Mediterranean Sea: Estimates, Patterns, and Threats (SJ Bograd, Ed.). PLoS One 5:1–36
Colloca F, Cardinale M, Maynou F, Giannoulaki M, Scarcella G, Jenko K, Bellido JM, Fiorentino F (2013) Rebuilding Mediterranean fisheries: A new paradigm for ecological sustainability. Fish Fish 14:89–109
Colloca F, Crespo V, Cerasi S, Coppola SR, Malouli Idrissi M, Zahri Y, Houssa R, Abdelaoui B, Ouamari N El (2003) Artisanal Fishery Communities in the Mediterranean: Two Case Studies. FAO, Rome, Italy
Consejero de Agricultura Ganadería y Pesca (1995) Decreto n.º 15/1995 de 31 de Marzo. Consejero de Agricultura Ganadería y Pesca
Cooper AB (2006) A Guide to fisheries stock assessment: from data to recommendations. :44
Costanza R (1999) The ecological, economic, and social importance of the oceans. Ecol Econ 31:199–213
Council of the European Union (2002) COUNCIL REGULATION (EC) No 2371/2002 of 20 December 2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy. Off J Eur Communities L358:59–80
Daw TM (2010) Shifting baselines and memory illusions: what should we worry about when inferring trends from resource user interviews? Anim Conserv 13:534–535
Daw T, Gray T (2005) Fisheries science and sustainability in international policy: a study of failure in the European Union's Common Fisheries Policy. Mar Policy 29:189–197
Diaz Pauli B, Sih A (2017) Behavioural responses to human-induced change: Why fishing should not be ignored. Evol Appl 10:231–240
Doubleday ZA, Prowse TAA, Arkhipkin A, Pierce GJ, Semmens J, Steer M, Leporati SC, Lourenço S, Quetglas A, Sauer W, Gillanders BM (2016) Global proliferation of cephalopods. Curr Biol 26:R406–R407
Edgar GJ, Bustamante RH, Fariña J-M, Calvopiña M, Martínez C, Toral-Granda MV (2004) Bias in evaluating the effects of marine protected areas: the importance of baseline data for the Galapagos Marine Reserve. Environ Conserv 31:212–218

Edgar GJ, Stuart-Smith RD, Willis TJ, Kininmonth S, Baker SC, Banks S, Barrett NS, Becerro MA, Bernard ATF, Berkhout J, Buxton CD, Campbell SJ, Cooper AT, Davey M, Edgar SC, Försterra G, Galván DE, Irigoyen AJ, Kushner DJ, Moura R, Parnell PE, Shears NT, Soler G, Strain EMA, Thomson RJ (2014) Global conservation outcomes depend on marine protected areas with five key features. Nature 506:216–20

Estrada M (1996) Primary production in the northwestern Mediterranean. Sci Mar 60:55–64

European Comission (2015) Fish stocks in Northeast Atlantic recover, whilst serious overfishing in Mediterranean : Commission sets out plans for 2015 fishing opportunities. Brussels

European Commission (2017a) Commission Decision (EU) 2017/848.

European Commission (2017b) Common Fisheries Policy. https://ec.europa.eu/fisheries/cfp_en

European Commission (2017c) Scientific advice on managing fish stocks. https://ec.europa.eu/fisheries/cfp/fishing_rules/scientific_advice_en

European Union (2014) Programmes of measures under the Marine Strategy Framework Directive: Recommendations for implementation and reporting.

FAO (1995) CODE OF CONDUCT FOR RESPONSIBLE FISHERIES. FAO, Rome

FAO (2002) Stopping illegal, unreported and unregulated fishing. Rome

FAO (2004) FAO Major Fishing Areas. MEDITERRANEAN AND BLACK SEA (Major Fishing Area 37). Rome

FAO (2005) General situation of world fish stocks. Review of the state of world marine fishery resources. Rev state world Mar Fish Resour 457:1;3

FAO (2016a) The State of World Fisheries and Aquaculture 2016. Rome

FAO (2016b) The State of the mediterranean and black sea fisheries 2016. Rome, Italy

Ferguson MAD, Williamson RG, Messier F (1998) Inuit knowledge of Long-term changes in a populaion of Arctic Tundra Caribou. Arctic 51:201–219

Fernandes PG, Cook RM (2013) Reversal of Fish Stock Decline in the Northeast Atlantic. Curr Biol 23:1432–1437

Fernandes PG, Ralph GM, Nieto A, García Criado M, Vasilakopoulos P, Maravelias CD, Cook RM, Pollom RA, Kovačić M, Pollard D, Farrell ED, Florin A-B, Polidoro BA, Lawson JM, Lorance P, Uiblein F, Craig M, Allen DJ, Fowler SL, Walls RHL, Comeros-Raynal MT, Harvey MS, Dureuil M, Biscoito M, Pollock C, McCully Phillips SR, Ellis JR, Papaconstantinou C, Soldo A, Keskin Ç, Knudsen SW, Gil de Sola L, Serena F, Collette BB, Nedreaas K, Stump E, Russell BC, Garcia S, Afonso P, Jung ABJ, Alvarez H, Delgado J, Dulvy NK, Carpenter KE (2017) Coherent assessments of Europe's marine fishes show regional divergence and megafauna loss. Nat Ecol Evol 1:170

Fisher J, Frank K, Leggett W (2010) Global variation in marine fish body size and its role in biodiversity–ecosystem functioning. Mar Ecol Prog Ser 405:1–13

Forcada A, Valle C, Sanchez-Lizaso JL, Bayle-Sempere JT, Corsi F (2010) Structure and spatio-temporal dynamics of artisanal fisheries around a Mediterranean marine protected area. ICES J Mar Sci 67:191–203

Franco A Di, Gillanders BM, Benedetto G De, Pennetta A, Leo GA De, Guidetti P (2012) Dispersal Patterns of Coastal Fish: Implications for Designing Networks of Marine Protected Areas (RKF Unsworth, Ed.). PLoS One 7:e31681

Franco A Di, Thiriet P, Carlo G Di, Dimitriadis C, Francour P, Gutiérrez NL, Jeudy de Grissac A, Koutsoubas D, Milazzo M, Otero M del M, Piante C, Plass-Johnson J, Sainz-Trapaga S, Santarossa L, Tudela S, Guidetti P (2016) Five key attributes can increase marine protected areas performance for small-scale fisheries management. Sci Rep 6:38135

Fromentin JM, Powers JE (2005) Atlantic bluefin tuna: Population dynamics, ecology, fisheries and management. Fish Fish 6:281–306

Gabrié C, Lagabrielle E, Bissery C, Crochelet E, Meola B, Webster C, Claudet J, Chassanite A, Marinesque S, Robert P, Goutx M, Quod C (2012) The Status of Marine Protected Areas in the Mediterranean Sea A study done by MedPAN (M Collection, Ed.).

Galil BS, Boero F, Campbell ML, Carlton JT, Cook E, Fraschetti S, Gollasch S, Hewitt CL, Jelmert A, Macpherson E, Marchini A, McKenzie C, Minchin D, Occhipinti-Ambrogi A, Ojaveer H, Olenin S, Piraino S, Ruiz GM (2014) "Double trouble": the expansion of the Suez Canal and marine bioinvasions in the Mediterranean Sea. Biol Invasions 17:973–976

García-Charton JA, Calò A, Codognotto-Capuzzo MS, Hernández Andreu RD, Irigoyen AJ, Pereñíguez López JM, Rojo Moreno I, Barcala Bellod E, Marcos C, Pérez Ruzafa Á (2015) Estudios de seguimiento de la Reserva Marina de Cabo de Palos-Islas Hormigas. Murcia

García-Charton JA, Hackradt CW, Fleix-Hackradt FC, Segovia Viadero M, Martínez Garrido J, González Andrés C, Tubío A, Sanchis Martínez A, Morcillo Buendía E, Trviño Otón J, Marcos Diego C, Pérez Ruzafa A (2010) Estudios de seguimiento de la reserva marina de Cabo de Palos – Islas Hormigas. Murcia, Spain

García-Charton JA, Pérez-Ruzafa A, Marcos C, Claudet J, Badalamenti F, Benedetti-Cecchi L, Falcón JM, Milazzo M, Schembri PJ, Stobart B, Vandeperre F, Brito A, Chemello R, Dimech M, Domenici P, Guala I, Diréach L Le, Maggi E, Planes S (2008) Effectiveness of European Atlanto-Mediterranean MPAs: Do they accomplish the expected effects on populations, communities and ecosystems? J Nat Conserv 16:193–221

Garcia-Charton JA, Perez-Ruzafa A, Sanchez-Jerez P, Bayle-Sempere JT, Renones O, Moreno D (2004) Multi-scale spatial heterogeneity, habitat structure, and the effect of marine reserves on Western Mediterranean rocky reef fish assemblages. Mar Biol 144:161–182

Gatti G, Bianchi CN, Parravicini V, Rovere A, Peirano A, Montefalcone M, Massa F, Morri C (2015) Ecological Change, Sliding Baselines and the Importance of Historical Data: Lessons from Combing Observational and Quantitative Data on a Temperate Reef Over 70 Years (AC Tsikliras, Ed.). PLoS One 10:e0118581

General Fisheries Commission for the Mediterranean (GFCM) (2017) Stock Assessement Priority List. FAO:1

Giorgi F, Lionello P (2008) Climate change projections for the Mediterranean region. Glob Planet Change 63:90–104

Gollasch S (2006) Overview on introduced aquatic species in European navigational and adjacent waters. Helgol Mar Res 60:84–89

Goñi R, Adlerstein S, Alvarez-Berastegui D, Forcada A, Reñones O, Criquet G, Polti S, Cadiou G, Valle C, Lenfant P, Bonhomme P, Pérez-Ruzafa A, Sánchez-Lizaso J, García-Charton J, Bernard G, Stelzenmüller V, Planes S (2008) Spillover from six western Mediterranean marine protected areas: evidence from artisanal fisheries. Mar Ecol Prog Ser 366:159–174

Goodman LA (1961) Snowball Sampling. Ann Math Stat 32:148–170

Grosholz E (2002) Ecological and evolutionary consequences of coastal invasions. Trends Ecol Evol 17:22–27

Guidetti P, Baiata P, Ballesteros E, Franco A Di, Hereu B, Macpherson E, Micheli F, Pais A, Panzalis P, Rosenberg AA, Zabala M, Sala E (2014) Large-Scale Assessment of Mediterranean Marine Protected Areas Effects on Fish Assemblages (BR MacKenzie, Ed.). PLoS One 9:e91841

Guidetti P, Milazzo M, Bussotti S, Molinari A, Murenu M, Pais A, Spanò N, Balzano R, Agardy T, Boero F, Carrada G, Cattaneo-Vietti R, Cau A, Chemello R, Greco S, Manganaro A, Notarbartolo di Sciara G, Russo GF, Tunesi L (2008) Italian marine reserve effectiveness: Does enforcement matter? Biol Conserv 141:699–709

Guilhaumon F, Albouy C, Claudet J, Velez L, Rais Lasram F Ben, Tomasini J-A, Douzery EJP, Meynard CN, Mouquet N, Troussellier M, Araújo MB, Mouillot D (2015) Representing taxonomic, phylogenetic and functional diversity: new challenges for Mediterranean marine-protected areas (S Ferrier, Ed.). Divers Distrib 21:175–187

Guyader O, Berthou P, Koutsikopoulos C, Alban F, Demanèche S, Gaspar MB, Eschbaum R, Fahy E, Tully O, Reynal L, Curtil O, Frangoudes K, Maynou F (2013) Small scale fisheries in Europe: A comparative analysis based on a selection of case studies. Fish Res 140:1–13

Halpern BS (2003) The Impact of Marine Reserves : Do Reserves Work and Does Reserve Size Matter? Ecol Appl 13:S117–S137

Halpern BS, Walbridge S, Selkoe KA, Kappel C V., Micheli F, D'Agrosa C, Bruno JF, Casey KS, Ebert C, Fox HE, Fujita R, Heinemann D, Lenihan HS, Madin EMP, Perry MT, Selig ER, Spalding M, Steneck R, Watson R (2008) A Global Map of Human Impact on Marine Ecosystems. Science (80-) 319:948–952

Hawkins SJ, Southward AJ, Genner MJ (2003) Detection of environmental change in a marine ecosystem--evidence from the western English Channel. Sci Total Environ 310:245–56

Heisler J, Glibert PM, Burkholder JM, Anderson DM, Cochlan W, Dennison WC, Dortch Q, Gobler CJ, Heil CA, Humphries E, Lewitus A, Magnien R, Marshall HG, Sellner K, Stockwell DA, Stoecker DK, Suddleson M (2008) Eutrophication and harmful algal blooms: A scientific consensus. Harmful Algae 8:3–13

Heithaus MR, Frid A, Wirsing AJ, Worm B (2008) Predicting ecological consequences of marine top predator declines. Trends Ecol Evol 23:202–210

Henriques S, Guilhaumon F, Villéger S, Amoroso S, França S, Pasquaud S, Cabral HN, Vasconcelos RP (2017) Biogeographical region and environmental conditions drive functional traits of estuarine fish assemblages worldwide. Fish Fish:1–20

Hilborn R (2007) Defining success in fisheries and conflicts in objectives. Mar Policy 31:153–158

Hoggarth DD, Abeyasekera S, Arthur RI, Beddingtion JR, Burn RW, Halls AS, Kirkwood GP, McAllister M, Medley P, Mees CC, Parkes GB, Pilling GM, Wakeford RC, Welcomme RL (2006) Stock assessment for fishery management, A frame guide to the stock assessment tools of the Fisheries Management Science Programme. FAO Fish Tech Pap:261

Honey KT, Moxley JH, Fujita RM (2010) From Rags to Fishes: Data-Poor Methods for Fishery Managers. Manag Data-Poor Fish Case Stud Model Solut 1:159–184

Huntington HP (2000) Using traditional ecological knowledge in science: methods and applications. Ecol Appl 10:1270–1274

Hutchings JA, Baum JK (2005) Measuring marine fish biodiversity: temporal changes in abundance, life history and demography. Philos Trans R Soc B Biol Sci 360:315–338

Hutchings JA, Myers RA (1994) What Can Be Learned from the Collapse of a Renewable Resource? Atlantic Cod, Gadus rnorhua, of Newfoundland and Labrador Jeffrey. Can J Fish Aquat Sci 51:2126–2146

Jackson JBC, Kirby MX, Berger WH, Bjorndal KA, Botsford LW, Bourque BJ, Bradbury RH, Cooke R, Erlandson J, Estes JA, Hughes TP, Kidwell S, Lange CB, Lenihan HS, Pandolfi M, Peterson CH, Steneck RS, Tegner MJ, Warner RR, Pandolfi JM (2001) Historical Collapse Overfishing of and the Recent Coastal Ecosystems. Science (80-) 293:629–638

Johannes RE, Freeman MMR, Hamilton RJ (2008) Ignore fishers' knowledge and miss the boat. Fish Fish 1:257–271

Juan Mohan S De, Demestre M (2007) Effects of commercial trawling activities on benthic communities in a fishing ground from the NW Mediterranean Sea. Dep Ecol 334:158 pp.

Karydis M, Kitsiou D (2012) Eutrophication and environmental policy in the Mediterranean Sea: a review. Environ Monit Assess 184:4931–4984

Katsanevakis S, Tempera F, Teixeira H (2016) Mapping the impact of alien species on marine ecosystems: the Mediterranean Sea case study (M Bode, Ed.). Divers Distrib 22:694–707

Kent G (1986) The Industrialization of Fisheries. Peasant Stud 13:133–143

Knowles JE, Doyle E, Schill SR, Roth LM, Milam A, Raber GT (2015) Establishing a marine conservation baseline for the insular Caribbean. Mar Policy 60:84–97

Knowlton N, Jackson JBC (2008) Shifting Baselines, Local Impacts, and Global Change on Coral Reefs. PLoS Biol 6:e54

Kurien J, Willmann R (2009) A Fishery Manager's Guidebook (KL Cochrane and SM Garcia, Eds.), 2nd edn. Wiley-Blackwell, Oxford, UK

Lavorel S, Garnier E (2002) Predicting changes in community composition and ecosystem functioning from plant traits: revisiting the Holy Grail. Funct Ecol 16:545–556

Lejeusne C, Chevaldonné P, Pergent-Martini C, Boudouresque CF, Pérez T (2010) Climate change effects on a miniature ocean: the highly diverse, highly impacted Mediterranean Sea. Trends Ecol Evol 25:250–260

Lenihan HS, Peterson CH (1998) How habitat degradation through fishery disturbance enhances impacts of hypoxia on oyester reefs. Ecol Appl 8:128–140

Liquete C, Piroddi C, Macías D, Druon J-N, Zulian G (2016) Ecosystem services sustainability in the Mediterranean Sea: assessment of status and trends using multiple modelling approaches. Sci Rep 6:34162

Litchman E, Klausmeier C a. (2008) Trait-Based Community Ecology of Phytoplankton. Annu Rev Ecol Evol Syst 39:615–639

Lleonart J, Maynou F (2003) Fish stock assessments in the Mediterranean: state of the art. Sci Mar 67:37–49

Long RD, Charles A, Stephenson RL (2015) Key principles of marine ecosystem-based management. Mar Policy 57:53–60

López A, Pierce G., Santos M., Gracia J, Guerra A (2003) Fishery by-catches of marine mammals in Galician waters: results from on-board observations and an interview survey of fishermen. Biol Conserv 111:25–40

Lorenzo M Di, Claudet J, Guidetti P (2016) Spillover from marine protected areas to adjacent fisheries has an ecological and a fishery component. J Nat Conserv 32:62–66

Lotze HK, Worm B (2009) Historical baselines for large marine animals. Trends Ecol Evol 24:254–262

Lozano-Montes HM, Pitcher TJ, Haggan N (2008) Shifting environmental and cognitive baselines in the upper Gulf of California. Front Ecol Environ 6:75–80

Markham HL, Browne NK (2007) Baseline survey protocol. Diving Sci 2007 Proc Am Acad Underw Sci:13–22

Maynou F, Sbrana M, Sartor P, Maravelias C, Kavadas S, Damalas D, Cartes JE, Osio G (2011) Estimating trends of population decline in long-lived marine species in the mediterranean sea based on fishers' perceptions. PLoS One 6

McGill BJ, Enquist BJ, Weiher E, Westoby M (2006) Rebuilding community ecology from functional traits. Trends Ecol Evol 21:178–185

Megalofonou P, Yannopoulos C, Damalas D, Metrio G De, Deflorio M, La Serna JM De, Macias D (2005) Incidental catch and estimated discards of pelagic sharks from the swordfish and tuna fisheries in the Mediterranean Sea. Fish Bull 103:620–634

Micheli F, Saenz-Arroyo A, Greenley A, Vazquez L, Espinoza Montes JA, Rossetto M, Leo GA De (2012) Evidence That Marine Reserves Enhance Resilience to Climatic Impacts (AP Klimley, Ed.). PLoS One 7:e40832

Ministerio de agricultura y pesca alimentación y medio ambiente (2016) Estadísticas Pesqueras: Noviembre 2016.

Moller H, Berkes F (2004) Combining science and traditional ecological knowledge: monitoring populations for co-management. Ecol Soc 9:15

Mora C, Tittensor DP, Adl S, Simpson AGB, Worm B (2011) How Many Species Are There on Earth and in the Ocean? (GM Mace, Ed.). PLoS Biol 9:e1001127

Morte S, Redon MJ, Sanz-Brau A (2001) Diet of Scorpaena porcus and Scorpaena notata (Pisces : Scorpaenidae) in the western Mediterranean. Cah Biol Mar Mar 42:333–344

Narayanaswamy BE, Coll M, Danovaro R, Davidson K, Ojaveer H, Renaud PE (2013) Synthesis of Knowledge on Marine Biodiversity in European Seas: From Census to Sustainable Management (KI Stergiou, Ed.). PLoS One 8:e58909

Occhipinti-Ambrogi A, Galil B (2010) Marine alien species as an aspect of global change. Adv Oceanogr Limnol 1:199–218

Oksanen J, Blanchet FG, Friendly M, Kindt R, Legendre P, McGlinn D, Minchin PR, O'Hara RB, Simpson GL, Solymos P, Stevens MHH, Szoecs E, Wagner H (2016) vegan: Community Ecology Package. R package version 2.4-1. https://CRAN.R-project.org/package=vegan.

Oliver P (2002) Methods for Assessing Mediterranean Fisheries. Rome

Palanques A, Guillén J, Puig P (2001) Impact of bottom trawling on water turbidity and muddy sediment of an unfished continental shelf. Limnol Oceanogr 46:1100–1110

Papworth SK, Rist J, Coad L, Milner-Gulland EJ (2009) Evidence for shifting baseline syndrome in conservation. Conserv Lett 2:93–100

Pauly D (1995) Anecdotes and the shifting baseline syndrome fisheries. Trends Ecol Evol 10:1995

Pauly D (1998) Fishing Down Marine Food Webs. Science (80-) 279:860–863

Pauly D (2010) TED - The ocean's shifting baseline.

Pauly D, Palomares ML, Froese R, Sa-a P, Vakily M, Preikshot D, Wallace S, Sa-a P (2001) Fishing down Canadian food webs aquatic. Can J Fish Aquat Sci 58:51–62

Pauly D, Ulman A, Piroddi C, Bultel E, Coll M (2014) "Reported" versus "likely" fisheries catches of four Mediterranean countries. Sci Mar 78:11–17

Peres MB, Klippel S (2003) Reproductive Biology of Southwestern Atlantic Wreckfish, Polyprion americanus (Teleostei: Polyprionidae). Environ Biol Fishes 68:163–173

Pérez-Ruzafa A, García-Charton JA, Barcala E, Marcos C (2006) Changes in benthic fish assemblages as a consequence of coastal works in a coastal lagoon: The Mar Menor (Spain, Western

Mediterranean). Mar Pollut Bull 53:107–120

Perez-Ruzafa A, Gilaber J, Gutierrez JM, Fernandez AI, Marcos C, Sabah S (2002) Evidence of a planktonic food web response to changes in nutrient input dynamics in the Mar Menor coastal lagoon, Spain (E Orive, M Elliot, and VN Jonge, Eds.). Nutr Eutrophication Estuaries Coast Waters 475/476:359–369

Perez-Ruzafa A, Marcos-Diego C, Ros JD (1991) Environmental and biological changes related to recent human activities in the Mar Menor (SE of Spain). Mar Pollut Bull 23:747–751

Perry AL (2005) Climate Change and Distribution Shifts in Marine Fishes. Science (80-) 308:1912–1915

Pierce GJ, Valavanis VD, Guerra A, Jereb P, Orsi-Relini L, Bellido JM, Katara I, Piatkowski U, Pereira J, Balguerias E, Sobrino I, Lefkaditou E, Wang J, Santurtun M, Boyle PR, Hastie LC, MacLeod CD, Smith JM, Viana M, González AF, Zuur AF (2008) A review of cephalopod–environment interactions in European Seas. Hydrobiologia 612:49–70

Pierre JI St., Kovalenko KE (2014) Effect of habitat complexity attributes on species richness. Ecosphere 5:art22

Pitcher TJ (1986) Functions of Shoaling Behaviour in Teleosts. In: The Behaviour of Teleost Fishes. Springer US, Boston, MA, p 294–337

Pitcher TJ (1995) The impact of pelagic fish behaviour on fisheries.

Quetglas A, Keller S, Massutí E (2015) Can Mediterranean cephalopod stocks be managed at MSY by 2020? The Balearic Islands as a case study. Fish Manag Ecol 22:349–358

R Core Team (2015) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Raitsos DE, Beaugrand G, Georgopoulos D, Zenetos A, Pancucci-Papadopoulou AM, Theocharis A, Papathanassiou E (2010) Global climate change amplifies the entry of tropical species into the eastern Mediterranean Sea. Limnol Oceanogr 55:1478–1484

Rasalato E, Maginnity Vi, Brunnschweiler JM (2010) Using local ecological knowledge to identify shark river habitats in Fiji (South Pacific). Environ Conserv 37:90–97

Reynolds JD, Dulvy NK, Goodwin NB, Hutchings JA (2005) Biology of extinction risk in marine fishes. Proc R Soc B Biol Sci 272:2337–2344

Roberts CM (2003) Our shifting perspectives on the oceans. Oryx 37:166–177

Roberts CM, Hawkins JP, Gell FR (2005) The role of marine reserves in achieving sustainable fisheries. Philos Trans R Soc B Biol Sci 360:123–132

Robinson AR, Leslie WG, Theocharis A, Lascaratos A (2001) Mediterranean Sea Circulation. In: Encyclopedia of Ocean Sciences. Elsevier, p 710–725

Rodhouse PGK, Pierce GJ, Nichols OC, Sauer WHH, Arkhipkin AI, Laptikhovsky V V, Lipiński MR, Ramos JE, Gras M, Kidokoro H, Sadayasu K, Pereira J, Lefkaditou E, Pita C, Gasalla M, Haimovici M, Sakai M, Downey N (2014) Environmental Effects on Cephalopod Population Dynamics. In: Advances in Cephalopod Science: Biology, Ecology, Cultivation and Fisheries.p 99–233

Roff D a (1984) The Evolution of Life History Parameters in Teleosts. Can J Fish Aquat Sci 41:989–1000

Romanuk TN, Hayward A, Hutchings JA (2011) Trophic level scales positively with body size in fishes. Glob Ecol Biogeogr 20:231–240

Sabine CL (2004) The Oceanic Sink for Anthropogenic CO2. Science (80-) 305:367–371

Sáenz-Arroyo A, Roberts CM, Torre J, Cariño-Olvera M, Enríquez-Andrade RR (2005) Rapidly shifting environmental baselines among fishers of the Gulf of California. Proc Biol Sci 272:1957–62

Sahrhage D, Lundbeck J (1992) A History of Fishing. Springer Berlin Heidelberg, Berlin, Heidelberg

Samoilys MA, Martin-Smith KM, Giles BG, Cabrera B, Anticamara JA, Brunio EO, Vincent ACJ (2007) Effectiveness of five small Philippines' coral reef reserves for fish populations depends on site-specific factors, particularly enforcement history. Biol Conserv 136:584–601

Sedberry GR, Andrade CAP, Carlin JL, Chapman RW, Luckhurst BE, Manooch CS, Menezes G, Thomsen B, Ulrich GF (1999) Wreckfish Polyprion americanus in the North Atlantic: Fisheries, Biology, and Management of a Widely Distributed and Long-Lived Fish. Am Fish Soc Symp 23:27–50

Selig ER, Longo C, Halpern BS, Best BD, Hardy D, Elfes CT, Scarborough C, Kleisner KM, Katona

SK (2013) Assessing Global Marine Biodiversity Status within a Coupled Socio-Ecological Perspective (F Guichard, Ed.). PLoS One 8:e60284

Sondre A (2003) On estimating the age composition of the commercial catch of Northeast Arctic cod from a sample of clusters. ICES J Mar Sci 60:297–303

South Atlantic Fishery Managment Council (1991) Fishery Management Plan for the Snapper-Grouper Fishery of the South Atlantic Region. :114

Spalding MD, Fox HE, Allen GR, Davidson N, Ferdaña Z a., Finlayson M, Halpern BS, Jorge M a., Lombana A, Lourie S a., Martin KD, Mcmanus E, Molnar J, Recchia C a., Robertson J (2007) Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. Bioscience 57:573

Stefanescu C, Rucabado J, Lloris D (1992) Depth-size trends in western Mediterranean demersal deep-sea fishes. Mar Ecol Prog Ser 81:205–213

Stergiou KI, Karpouzi VS (2001) Feeding habits and trophic levels of Mediterranean fish. Rev Fish Biol Fish 11:217–254

Sumaila UR, Pauly D (2006) Catching More Bait: A bottom-up re-estimation of global fisheries subsidies. Fish Cent Res Rep 14:1–84

The European Parliament and the Council of the European Union (2008) Directive 2008/56/EC of the European Parliament and of the Council. Off J Eur Union 164:19–40

Tillin H, Hiddink J, Jennings S, Kaiser M (2006) Chronic bottom trawling alters the functional composition of benthic invertebrate communities on a sea-basin scale. Mar Ecol Prog Ser 318:31–45

Travis J, Coleman FC, Auster PJ, Cury PM, Estes JA, Orensanz J, Peterson CH, Power ME, Steneck RS, Wootton JT (2014) Integrating the invisible fabric of nature into fisheries management. Proc Natl Acad Sci 111:581–584

Tudela S (2004) Ecosystem effects of fishing in the mediterranean. An analysis of the major threats of fishing gear and practices to biodiversity and marine habitats.

Turner SJ, Thrush SF, Hewitt JE, Cummings VJ, Funnell G (1999) Fishing impacts and the degradation or loss of habitat structure. Fish Manag Ecol 6:401–420

Vandeperre F, Higgins RM, Sénchez-Meca J, Maynou F, Goéi R, Martén-Sosa P, Pérez-Ruzafa A, Afonso P, Bertocci I, Crec'hriou R, D'Anna G, Dimech M, Dorta C, Esparza O, Falcén JM, Forcada A, Guala I, Direach L Le, Marcos C, Ojeda-Marténez C, Pipitone C, Schembri PJ, Stelzenméller V, Stobart B, Santos RS (2011) Effects of no-take area size and age of marine protected areas on fisheries yields: A meta-analytical approach. Fish Fish 12:412–426

Vasilakopoulos P, Maravelias CD, Tserpes G (2014) The Alarming Decline of Mediterranean Fish Stocks. Curr Biol 24:1643–1648

Velasco J, Lloret J, Millan A, Marin A, Barahona J, Abellan P, Sanchez-Fernandez D (2006) Nutrient And Particulate Inputs Into The Mar Menor Lagoon (Se Spain) From An Intensive Agricultural Watershed. Water Air Soil Pollut 176:37–56

Violle C, Reich PB, Pacala SW, Enquist BJ, Kattge J (2014) The emergence and promise of functional biogeography. Proc Natl Acad Sci 111:13690–13696

Wickham H (2007) Reshaping Data with the reshape Package. Journal of Statistical Software, 21(12), 1-20. URL http://www.jstatsoft.org/v21/i12/.

Wickham H (2017) tidyr: Easily Tidy Data with "spread()" and "gather()" Functions. R package version 0.6.1. https://CRAN.R-project.org/package=tidyr.

Worm B, Barbier EB, Beaumont N, Duffy JE, Folke C, Halpern BS, Jackson JBC, Lotze HK, Micheli F, Palumbi SR, Sala E, Selkoe KA, Stachowicz JJ, Watson R (2006) Impacts of Biodiversity Loss on Ocean Ecosystem Services. Science (80-) 314:787–790

WWF (2016) A vision for Healthy fisheries in the Mediterranean.

Zerhouni EA (2004) Ecosystem-Based Fishery Management. Science (80-) 306:1895–1895

APPENDICES

Appendix I: Composition of the fishers' questionnaires, respective fish matrixes and ports maps.

UNIVERSIDAD DE MURCIA

Shifting environmental baselines of top predators in marine protected areas is a study included in a project conducted by the university of Murcia and financed by the department of Economy and competitively and Séneca foundation (Autonomous Community of the Region of Murcia), coordinated with the CIESM (www.ciesm.org) that studies marine sciences of the Mediterranean and Black seas.

This study's main objective is to describe the temporal evolution of the fishing captures since the 70s within the region o Murcia and how did the fishing effort shifted since that period. With the help of fishers from this region, through the interviews, will be possible to understand your perception of the shifting in fisheries and climate change. This information will be used to help scientific knowledge about the shifting baseline syndrome and help in decision-making for the management and conservation of marine ecosystems and sustainable fisheries like the artisanal.

The information collected in this project may be published and/or presented in different platforms like reports, scientific magazines and presented in scientific congresses or informative talks. It's intended to inform the scientific, management and political sectors and the public in general as well.

All the information presented by you is anonymous and is protected under the *Ley Orgánica 15/1999*, of 13 of December, of *Protecion de Datos de Carácter Personal*. This ensures that your intervention in the project does not pose any risk to you.

Your involvement in this is voluntary and you are free to renounce your participation in this inquiry and/or any of the information already given in anytime without any explanation. Please, read the following sentences carefully and if you agree, sign the document as an informed consent to take part in this inquiry and authorize the storage of the given information in the University of Murcia.

The interviewers are making this investigation with the University of Murcia, you can contact them at any time in case of doubt or provide further data.

Thank you very much for your collaboration in our study.

Appendix I. (Continued)

The undersigned confirms that (mark with and X the appropriate sentences):

1.	I have read and understood all the information about the investigation project and I authorized the making of the following questions in this questionnaire.	☐
2.	I have understood the voluntary character of this inquiry, and I'm free to leave any time without explanation.	☐
3.	I have understood that any information provided by me will be used anonymously and that I will not be identified when my opinions and perspectives be presented to other or in any publication or report.	☐
4.	The use of data in investigation and future publications that may arise have been sufficiently explained to me.	☐
5.	I agree in signing and put the date on this impress that I am in consent and informed.	☐

Participant

______________________ ______________

Signature Date

Researcher

________________________ __________________ ______________

Name of researcher Signature Date

Appendix I. (Continued)

Inquiry to artisanal fishers

Location (ES): _________________

Code: ________________

Date: ____________

I – PEARSONAL INFORMATION:

1 – Age: ____

2 – Gender: M F

3 – When start fishing (1º year of fishing): ______

II – VESSEL

4 – In which vessels you work and how many timed?

Name of vessel	Power (kW)	Nº of fishers	Length (m)	Since…to (year)

III – SHIFTING BASELINES

5 – Which species you have fished since start fishing (for each taxa)?

5.1 – How did fisheries have changed since the 1970? From 5 (fishing a lot every day) to 0 (never caught)

5.2 – Which gear, in general, you used to catch that species?

5.3 – Which was your biggest catch in one day (taxa, weight, number, year, month, gear)?

5.4 – Which was the biggest fish you ever caught (taxa, size, gear)?

Appendix I. (Continued)

INTERVIEW NUMBER................................ DATE....................... COMPILER...................................... Location......................... Country..................

NAME INTERVIEWED...Age.........................SINCE (year)...............................PROFESSIONAL □ SPORTIVE □

Scuba diver □ *Spear fishing* □ *Trammel net* □ *Purse seine* □ *Traps* □ *Hooks* □ *Trawl* □ *Others* ....

TRUSTWORTHINESS OF INTERVIEW

HIGH (VERY TRUSTHWORTHY) □

MEDIUM (ACCEPTABLE) □

LOW (DOUBTFUL) □

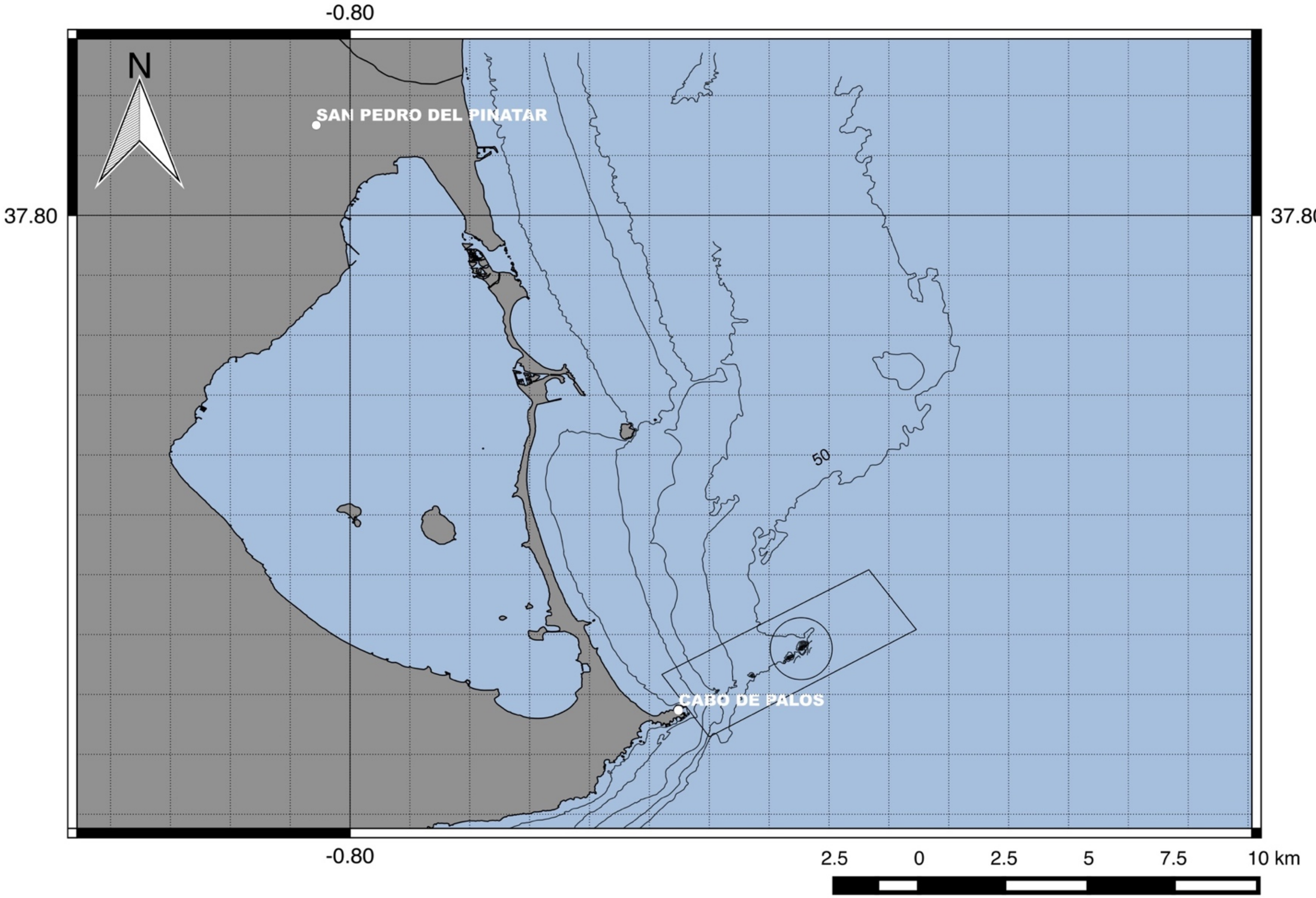
0=ABSENT; **1**=RARE (once in a year); **2**= OCCASIONAL (sometimes in a year); **3**= COMMON (regurarly in a year); **4**=ABUNDANT (regularly in captures and abundant); **5**=DOMINANT (always in captures and with great abundances)

SPECIES	RANK	<1970	1970										1980										1990										2000											2010						I Increase, D Decrease, F Fluctuant (I/D/F)
			70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	
	5																																																	
	4																																																	
	3																																																	
	2																																																	
	1																																																	
	0																																																	
MAX DAY CAPTURE (Absolute): Tot Kg....................... N.Individuals................ .Year...................... month.................. fishing gear............................																																																		
	5																																																	
	4																																																	
	3																																																	
	2																																																	
	1																																																	
	0																																																	
MAX DAY CAPTURE (Absolute): Tot Kg....................... N.Individuals................ .Year...................... month.................. fishing gear............................																																																		
	5																																																	
	4																																																	
	3																																																	
	2																																																	
	1																																																	
	0																																																	
MAX DAY CAPTURE (Absolute): Tot Kg....................... N.Individuals................ .Year...................... month.................. fishing gear............................																																																		
	5																																																	
	4																																																	
	3																																																	
	2																																																	
	1																																																	
	0																																																	
MAX DAY CAPTURE (Absolute): Tot Kg....................... N.Individuals................ .Year...................... month.................. fishing gear............................																																																		
	5																																																	
	4																																																	
	3																																																	
	2																																																	
	1																																																	
	0																																																	
MAX DAY CAPTURE (Absolute): Tot Kg....................... N.Individuals................ .Year...................... month.................. fishing gear............................																																																		
	5																																																	
	4																																																	
	3																																																	
	2																																																	
	1																																																	
	0																																																	
MAX DAY CAPTURE (Absolute): Tot Kg....................... N.Individuals................ .Year...................... month.................. fishing gear............................																																																		

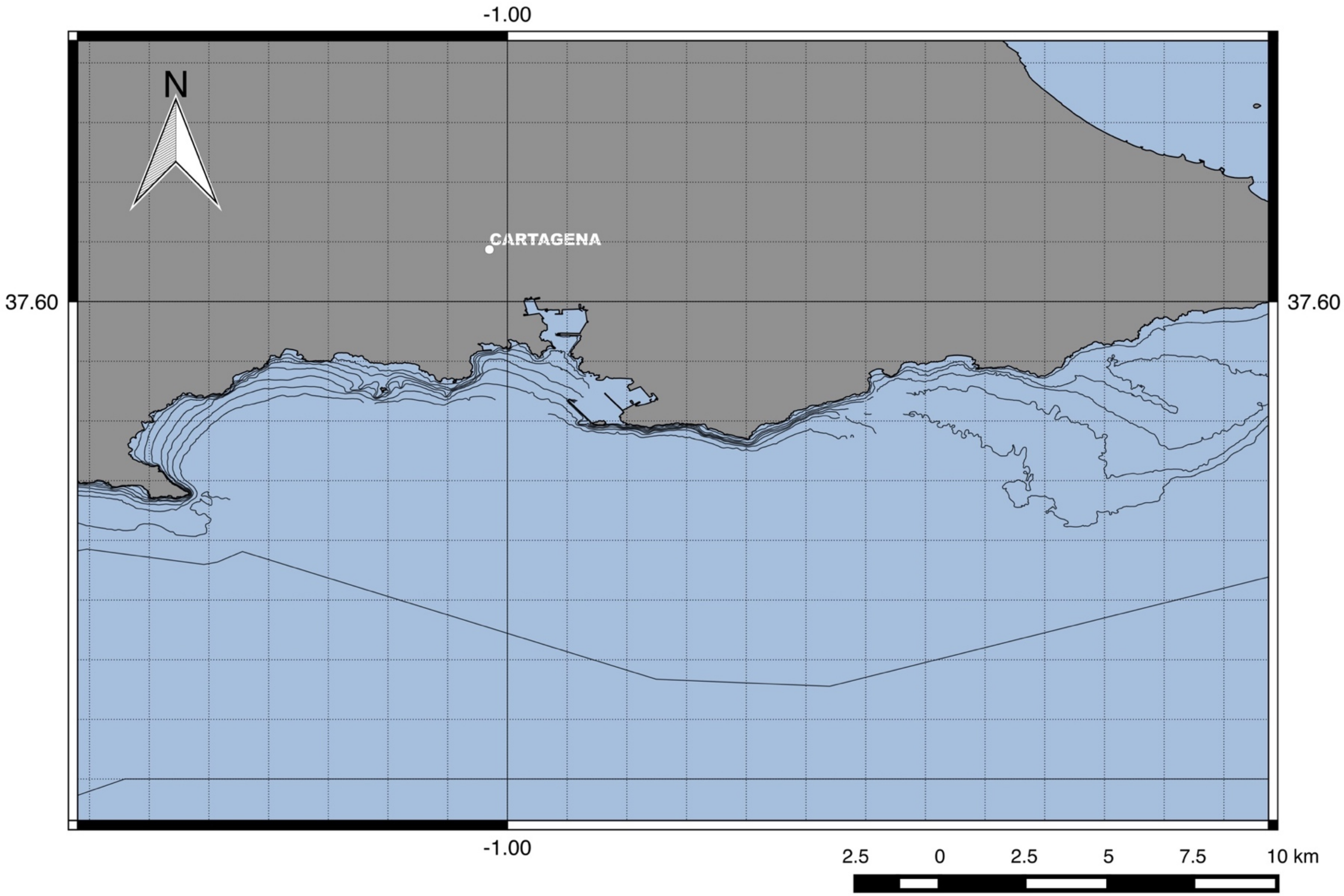
Appendix I. (Continued)

7 – Which are the fishing grounds that you used in the 70s, 80s, 90s, 2000s and now (2016)?

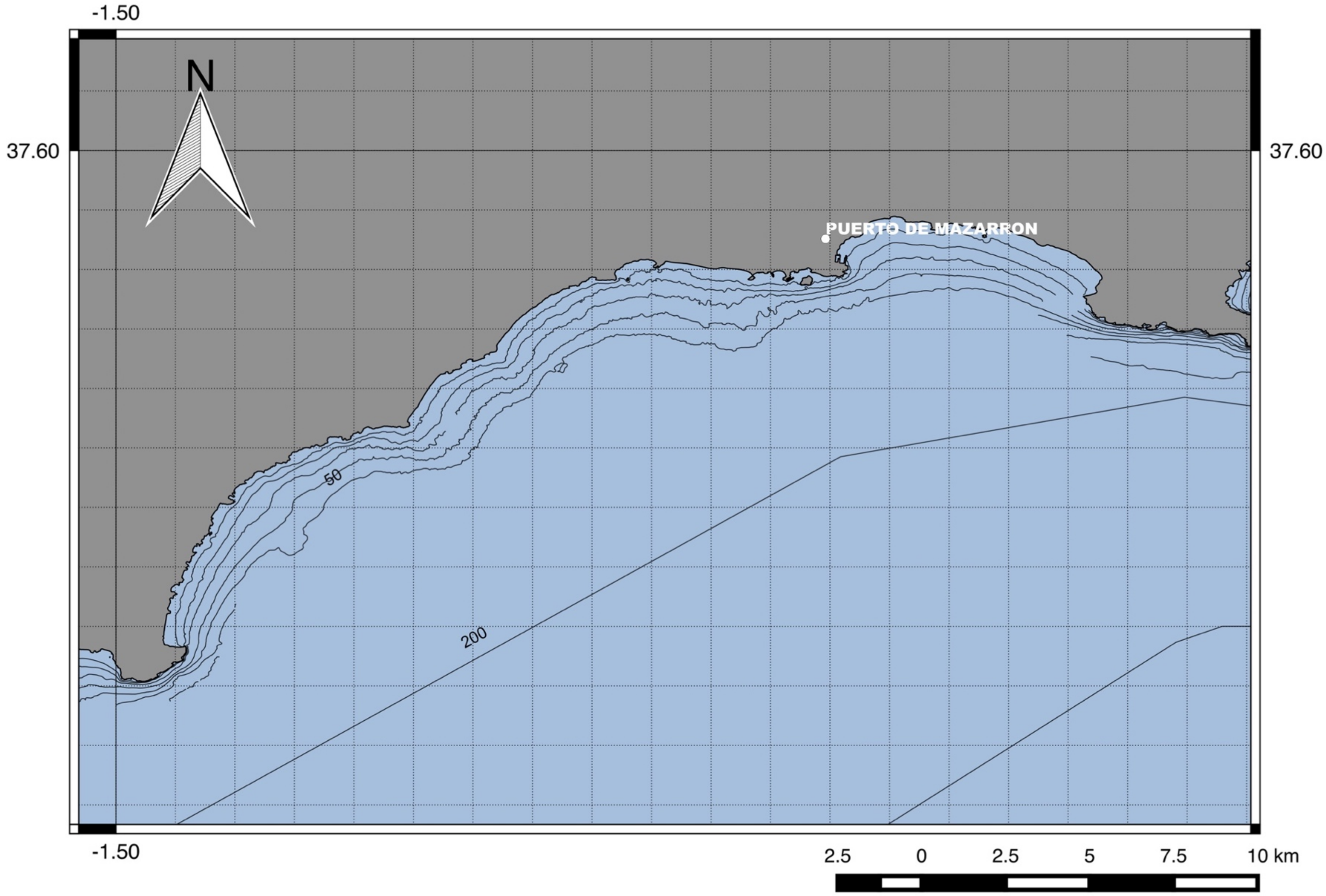
Appendix I. (Continued)



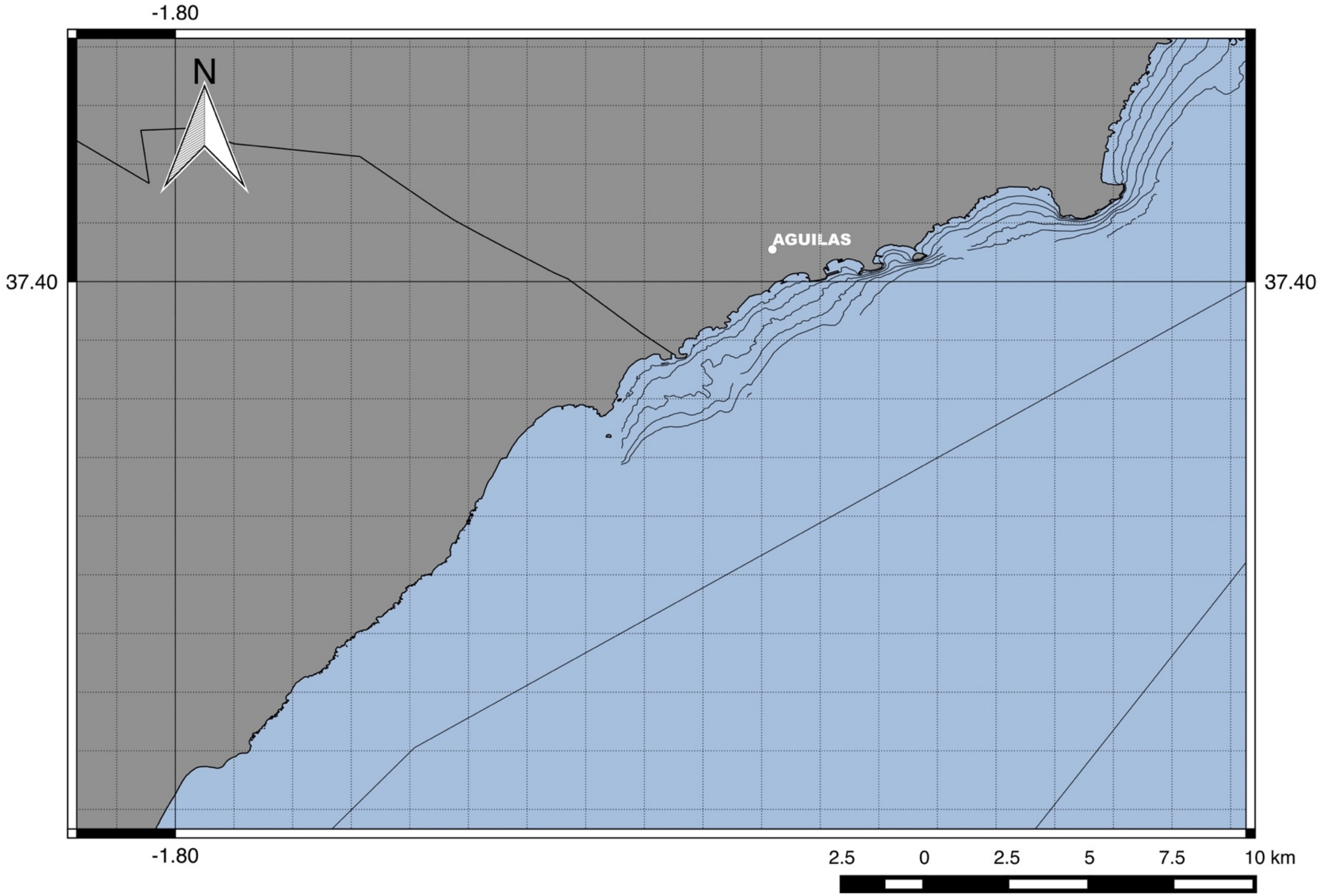
Appendix I. (Continued)



Appendix I. (Continued)



Appendix I. (Continued)



Appendix I. (Continued)

8 – Is there any species that disappeared (rarely seen today) since when you start fishing (taxa, when)?

9 – Do you recognize any change in the average fishing length of commercial fish (taxa, size before and now, year before and now)?

Appendix I. (Continued)

Code: __________

Species	Lenght (before)	Year (before)	Lenght (now)	Year (now)

Appendix I. (Continued)

IV – CLIMATE CHANGE:

10 – Is there any species that have increased or decreased since you started fishing (taxa, how much and when; if you don't recognize describe it)?

Appendix I. (Continued)

SHEET 2: 'RECORDS' **Can you tell us if there are some species that have appeared in the last years but that were not present before?** (see target species but ask also for new unidentified species)

INTERVIEW NUMBER................ DATE... COMPILER................................ Location.. Country..................

NAME INTERVIEWED.. Age......................... SINCE (year).. PROFESSIONAL ☐ SPORTIVE ☐

Scuba diver ☐ Spear fishing ☐ Trammel net ☐ Purse seine ☐ Traps ☐ Hooks ☐ Trawl ☐ Others ....

Do you regularely fish in the harbour? YES ☐ NO ☐ What kind of gear do you use to fish into the harbour? ... Hooks ☐ NETS ☐ TRAPS ☐ OTHER (SPECIFY) ☐ ....

SPECIES * *do you think is exotic or no?*	Yes/ no	year	month	N. Ind.	Depth	**Location** (and coordinates if available)	Fishing meth	Picture?**	**Notes**

If the interviewed has observed/captured something we can not identify write:* ***No Idendentified* *and report general description (lenght, weight, color, shape..)*

***Ask if he/she took pictures of the species (in this case try to get it)*

Availability to collaborate
LOW ☐ MED. ☐ HIGH ☐

Trustworthy (quality of the interview)
LOW ☐ MED. ☐ HIGH ☐

Appendix I. (Continued)

V – FISHING EFFORT

11 – How many days a week, on average, you go fish in past decades and now?

1970	1980	1990	2000	2010	2016

12 – How many hours a day did the fishing activity last in past decades and today?

1970	1980	1990	2000	2010	2016

13 – What was the average fishing depth (in meters) in past decades and today?

1970	1980	1990	2000	2010	2016

VI – SEA BIRDS BYCATCH

14 – Sea birds affect your activity?

YES NO

14.1 – If YES, in which way?

BENEFIT DETRIMENT INDIFERENTE

15 – How many birds do you catch while fishing per week?

R: _____

16 – The fishing gear damages are?

HIGH AVERAGE LOW N/NS

17 – Witch fishing gear catches more sea birds? Which species is it and during what season?

Fishing gear: _______________

Species: __________________

Season: __________________

Appendix II. List of mentioned species/group of species (31) and the respective traits related to commercial or bycatch value, maximum adult size, maximum adult depth, adult schooling behaviour, yearly displacement for ontogeny or reproduction, territoriality, mobility and diet. *Indicates non-fish species/groups of species.

Species/groups of species	**Maximum size**	**Adult depth**	**Adult habitat**	**Diet**	**Schooling behaviour**	**Territoriality**	**Yearly displacement**	**Mobility**	**Commercial or bycatch value**
Sarda sarda	large	medium	pelagic	macrocarnivore	schooler	non-territorial	large	very vagile	commercial
Xiphias gladius	very large	very deep	pelagic	macrocarnivore	solitary	non-territorial	large	very vagile	commercial
Mullus surmuletus	medium	deep	benthic	invertebrate feeder	facultative schooler	non-territorial	medium	vagile	commercial
Seriola dumerili	very large	deep	pelagic	macrocarnivore	solitary	non-territorial	large	very vagile	commercial
*Sepia officinalis**	medium	medium	demersal	macrocarnivore	solitary	territorial	large	vagile	commercial
*Octopus vulgaris**	medium	medium	benthic	invertebrate feeder	solitary	territorial	small	sedentary	commercial
Diplodus sargus	medium	shallow	demersal	omnivorous	facultative schooler	non-territorial	medium	vagile	commercial
Spaurus aurata	large	medium	demersal	invertebrate feeder	facultative schooler	non-territorial	large	vagile	commercial
Epinephelus sp.	very large	deep	benthic	macrocarnivore	solitary	territorial	small	vagile	commercial
*Palinurus sp.**	small	medium	benthic	omnivorous	facultative schooler	territorial	medium	sedentary	commercial
*Homarus gammarus**	medium	medium	benthic	omnivorous	solitary	territorial	large	sedentary	commercial
Scorpaenidae	medium	very deep	demersal	macrocarnivore	solitary	territorial	medium	sedentary	commercial
Zeus faber	large	deep	demersal	macrocarnivore	solitary	non-territorial	large	vagile	commercial
Loliginidae*	medium	deep	demersal	macrocarnivore	schooler	non-territorial	large	very vagile	commercial
Sciaena umbra	large	medium	demersal	invertebrate feeder	facultative schooler	non-territorial	medium	vagile	commercial

Appendix II. (Continued)

Species/groups of species	**Maximum size**	**Adult depth**	**Adult habitat**	**Diet**	**Schooling behaviour**	**Territoriality**	**Yearly displacement**	**Mobility**	**Commercial or bycatch value**
Dentex dentex	large	medium	demersal	macrocarnivore	facultative schooler	non-territorial	large	vagile	commercial
Aphia minuta	small	medium	pelagic	planktonivore	schooler	non-territorial	medium	vagile	commercial
Argyrosomus regius	very large	deep	demersal	macrocarnivore	facultative schooler	non-territorial	large	vagile	commercial
Pagellus erythrinus	medium	deep	demersal	macrocarnivore	facultative schooler	non-territorial	large	vagile	commercial
Auxis rochei	medium	medium	pelagic	macrocarnivore	schooler	non-territorial	large	very vagile	commercial
Merluccius merluccius	very large	deep	demersal	macrocarnivore	facultative schooler	non-territorial	large	vagile	commercial
Thunnus sp.	very large	very deep	pelagic	macrocarnivore	schooler	non-territorial	large	very vagile	commercial
Polyprion americanus	very large	very deep	demersal	macrocarnivore	solitary	territorial	large	vagile	commercial
Pagellus bogaraveo	large	very deep	demersal	invertebrate feeder	facultative schooler	non-territorial	large	vagile	commercial
Squaliformes	very large	very deep	demersal	macrocarnivore	facultative schooler	non-territorial	large	very vagile	commercial
Pagrus pagrus	large	deep	demersal	macrocarnivore	solitary	non-territorial	large	vagile	commercial
Boops boops	medium	deep	demersal	omnivorous	schooler	non-territorial	large	very vagile	commercial
Euthynnus alletteratus	very large	medium	pelagic	macrocarnivore	schooler	non-territorial	large	very vagile	commercial
*Palaemon sp.**	small	medium	demersal	planktonivore	schooler	non-territorial	medium	vagile	commercial

Appendix II. (Continued)

Species/groups of species	Maximum size	Adult depth	Adult habitat	Diet	Schooling behaviour	Territoriality	Yearly displacement	Mobility	Commercial or bycatch value
Cheilopogon heterurus	medium	shallow	pelagic	invertebrate feeder	schooler	non-territorial	large	very vagile	non-commercial
Sphyraena sp.	very large	medium	pelagic	macrocarnivore	solitary	non-territorial	large	very vagile	commercial